PETITION TO LIST
THE SONORAN DESERT TORTOISE *(Gopherus agassizii)*
UNDER THE U.S. ENDANGERED SPECIES ACT

Photo courtesy of George Andrejko ©

In the Office of Endangered Species
U.S. Fish and Wildlife Service
United States Department of Interior

October 9, 2008

Petitioners:

WildEarth Guardians
312 Montezuma Ave.
Santa Fe, New Mexico
87501
(505) 988-9126

Western Watersheds Project
P.O. Box 2364
Reseda, California 91337
(818) 345-0425

October 9, 2008

SENT VIA CERTIFIED U.S. POSTAL MAIL

Dirk Kempthorne
Secretary of the Interior
U.S. Department of the Interior
1849 C Street NW
Washington, DC 20240

Dale Hall, Director
U.S. Fish and Wildlife Service
U.S. Department of the Interior
1849 C Street NW
Washington, DC 20240

Dr. Benjamin Tuggle, Regional Director
U.S. Fish and Wildlife Service
P.O. Box 1306
Albuquerque, NM 87103

Re: Petition to List the Sonoran Desert Tortoise (*Gopherus agassizii)* as threatened or endangered under the Endangered Species Act

The following petitioners hereby petition for a rule to list the Sonoran desert tortoise (*Gopherus agassizii)* as "threatened" or "endangered" under the Endangered Species Act and to designate critical habitat to ensure its recovery (16 U.S.C § 1531 *et seq.*):

- **WildEarth Guardians**

WildEarth Guardians is a regional conservation organization with offices in Arizona, Colorado, and New Mexico. The mission of WildEarth Guardians is to protect and restore wildlife, wild rivers, and wild places in the American West.

- **Western Watersheds Project**

Western Watersheds Project is a regional conservation organization with offices in Arizona, California, Idaho, Montana, Utah, and Wyoming. The mission of Western Watersheds Project is to protect and restore western watersheds and wildlife habitats through education, scientific study, public policy initiatives, and litigation.

This petition is filed under 5 U.S.C. § 553(e), 16 U.S.C. § 1533(b)(3)(A) and 50 C.F.R. § 424.19, which give interested persons the right to petition for the issuance of a rule.

Sincerely,

Nicole Rosmarino, Ph.D.
Wildlife Program Director
WildEarth Guardians
<nrosmarino@wildearthguardians.org>

Michael J. Connor, Ph.D.
California Director
Western Watersheds Project
<mjconnor@westernwatersheds.org>

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

APPENDICES

I. EXECUTIVE SUMMARY

This petition presents substantial new scientific evidence of recent and rapid declines in monitored populations of Sonoran desert tortoise in Arizona.

The petition also demonstrates that Sonoran desert tortoises fully meet the criteria for listing as a distinct population segment (DPS) under the Endangered Species Act (ESA).

The petition provides clear evidence that monitored populations of Sonoran desert tortoise (SDT) have experienced statistically significant declines at the rate of 3.5% per year between 1987 and 2006. This decline equates to a total estimated 51% reduction in the number of monitored Sonoran desert tortoise adults and subadults since 1987.

Petitioners therefore request that the U.S. Fish and Wildlife Service (USFWS) list the Sonoran Desert distinct population segment of the desert tortoise[1] as Threatened or Endangered, that critical habitat be designated, and that a recovery plan be developed and implemented under the ESA (16 U.S.C. § 1531 et seq.).

[1]This petition also includes a request for federal listing of desert tortoises occurring in the Black Mountains north of Kingman, Arizona (as illustrated in Figure 1). As discussed below, we are consistent with the USFWS by including the Black Mountain tortoise population under the Sonoran Desert Tortoise umbrella for the purposes of this petition.

II. INTRODUCTION

Desert tortoises in the southwestern United States are increasingly at risk from both natural and human-caused threats, a fact that scientists and land managers will confront more and more frequently in the twenty-first century. This petition presents substantial new scientific evidence of recent and rapid declines in the population overall and among monitored Sonoran desert tortoise (SDT) populations. It also demonstrates that Sonoran desert tortoises meet the criteria for listing under the Endangered Species Act (ESA). Petitioners therefore request that the U.S. Fish and Wildlife Service (USFWS) list the Sonoran Desert distinct population segment of the desert tortoise as Threatened or Endangered under the ESA (16 U.S.C. § 1531 *et seq.*).

The first desert tortoises to be afforded federal protection were those of the Beaver Dam Slope population in Utah (USFWS 1980). In August of 1980 the USFWS listed that population as Threatened under the ESA and designated critical habitat for it (USFWS 1994b). In 1984, several conservation groups petitioned USFWS to list the desert tortoise as endangered throughout its range in Arizona, California and Nevada, and in 1985 the proposed listing was found by USFWS to be warranted but precluded because of higher priorities (USFWS 1994b). The warranted but precluded status of the desert tortoise was reaffirmed by USFWS each year through 1989, when the original petitioners presented new information on mortality rates among desert tortoises and proposed an emergency listing procedure for the entire species (including Sonoran, Mojave, and Beaver Dam Slope populations). The action resulted in an emergency listing of the Mojave population, those tortoises north and west of the Colorado River (excluding the Beaver Dam Slope population), as endangered on August 4, 1989 (USFWS 1989). Ultimately, the entire Mojave population of the desert tortoise was listed as threatened in April of 1990 under normal listing procedures (USFWS 1990).

In the final rule listing the Mojave desert tortoise population, USFWS described the primary reasons for authorizing protection of the species under the ESA as:

> …deterioration and loss of habitat, collection for pets and other purposes, elevated levels of predation, loss of desert tortoises from disease, and the inadequacy of existing regulatory mechanisms to protect desert tortoises and their habitat (USFWS 1989).

In 1994, USFWS designated critical habitat for Mojave segments of the desert tortoise (USFWS 1994a). These areas included over 2 million acres of habitat in northwest Arizona premised on proposed Desert Wildlife Management Areas (DWMAs) originally conceived in the Draft Recovery Plan for the Desert Tortoise (USFWS 1994a). The DWMAs were themselves based on morphologic, ecologic, genetic, and demographic data from tortoises, as well as a minimum size, proximity and connectivity necessary to maintain viable populations of desert tortoises (USFWS 1994b).

In 1991, USFWS found that listing of the SDT (those south and east of the Colorado River) was not warranted (USFWS 1991). USFWS based these findings principally on an apparent lack of disease outbreaks, the claim that SDT populations are isolated from each other and diseases are less likely to spread between adjacent populations, and an assertion that the rocky habitats found in the Sonoran Desert are less likely to receive high levels of human disturbance than are the flatter, more easily developed lands of the Mojave desert (Turner 1982, Barrett and Johnson 1990).

Unfortunately for the tortoise, the intervening 17 years since the USFWS's decision not to provide federal protection have provided evidence showing that SDTs do indeed suffer from many of the same threats that led to the listing of the Mojave populations. Disease now exists within some populations, development pressures are increasingly isolating local populations making them more susceptible to stochastic events and demographic issues, and grazing and other activities threaten populations even in hilly areas. While the ESA requires listing if a species meets just one of five listing criteria, the SDT meets multiple criteria and therefore warrants protection under the Endangered Species Act.

A number of tortoises have tested positive or marginally positive for exposure to at least one of the *Mycoplasma* species that cause Upper Respiratory Tract Disease (URTD). Tortoises with possible clinical signs of URTD have been found on 11 of 16 study plots. Tortoises on 15 of the same 16 study plots exhibited Cutaneous Dyskeratosis (CD), a disease primarily of the plastron and carapace that causes degeneration and lesions of the tissue (Jacobson et al. 1994, Dickinson et al. 1996, Averill-Murray 2000, Dickenson et al. 2002). Thus, almost all study populations had at least one individual with symptoms of one of those diseases (69% for clinical signs of URTD, 94% for CD).

Development has significantly accelerated since USFWS's 1991 determination that the listing of the SDT was not warranted. Major federal projects that have impacted the tortoise have included the continued construction and on-going operations of the massive Central Arizona Project (CAP), construction and operations of over a dozen quarry sites on the lower Colorado River operated by the Bureau of Reclamation, the issuance of several thousand permits for impacts to washes by the Core of Engineers, and the authorization of numerous federal rights-of-way, to name but a few examples. Energy developments (including renewable energy projects) and transmission lines pose a growing threat to tortoise populations and habitat. For example, the Bureau of Land Management (BLM) is developing a Programmatic Environmental Impact Statement (PEIS) to facilitate utility-scale solar energy development in six western states including Arizona over the next 20 years (Department of Energy and Bureau of Land Management, 2008).

Additionally, there has been an enormous increase in extractive uses on BLM lands, which comprise the majority of SDT habitat in Arizona. Among these is livestock grazing across almost six million acres (within 273 grazing allotments), or 78% of BLM classified desert tortoise habitat. From 1990-2002, the BLM listed 9,675 new mining claims, 36% of which are within BLM classified tortoise habitat.

Additional impacts to SDTs are increased urbanization and agricultural development in southern Arizona, which fragments and degrades tortoise habitat. A related impact is increased predation from human-subsidized populations of ravens and canids (Averill-Murray 2000; Boarman 2002b).

These threats are very likely important determinants of the significant declines in desert tortoise populations that have occurred over the past 20 years (See Section on Population Abundance and Trends below). A recent analysis (see appendix 3) shows that the Sonoran population of the desert tortoise has experienced statistically significant declines of 3.5% per year between 1987 and 2006 (Appendix 3). This equates to an estimated 51% reduction in the number of adults and subadults on study plots between 1987 and 2006. The population on one plot (Maricopa Mountains) has dropped an estimated 90% since 1991. The magnitude, swiftness, and pervasiveness in declines across the tortoises' range require immediate action by the USFWS to protect the SDT under the ESA.

III. ENDANGERED SPECIES ACT IMPLEMENTING REGULATIONS

Section 424 of the regulations implementing the ESA (16 U.S.C. § 1531 *et seq*.; 50 C.F.R. § 424) is applicable to this petition. Subsections that concern the formal listing of the SDT as an Endangered or Threatened species are:

> 424.02(e) "Endangered species" means a species that is in danger of extinction throughout all or a significant portion of its range."…(k) "species" includes any species or subspecies that interbreeds when mature.
>
> "Threatened species" means a species that "is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" (16 U.S.C § 1532(20)).
>
> 424.11(c) "A species shall be listed…because of any one or a combination of the following factors:
>
> 1. The present or threatened destruction, modification, or curtailment of habitat or range;
> 2. Overutilization for commercial, recreational, scientific, or educational purposes;
> 3. Disease or predation;
> 4. The inadequacy of existing regulatory mechanisms; and
> 5. Other natural or manmade factors affecting its continued existence."

All of the five factors set forth in 424.11(c) have, to varying degrees, resulted in the continued decline of the SDT and are causing populations to face endangerment and extinction. Therefore, Petitioners request that the SDT, whose range comprises west-central Arizona to central Sonora, Mexico, be listed as threatened or endangered across its range.

IV. LIFE HISTORY

Community Associations

SDT populations are found primarily on the rocky slopes and bajadas of Mojave Desert Scrub communities and within the Arizona Upland and Lower Colorado River Valley subdivisions of the Sonoran Desert Scrub community and are often associated with palo verde-mixed cacti dominated landscapes (Burge 1980, Lawler 1986, Bury et al. 1994, Schneider 1981, Turner and Brown 1982, Vaughn 1984, Barrett 1990, Germano et al. 1994, Averill-Murray and Klug 2000). In some areas such as the Florence Military Reservation (FMR) in Pinal County, SDT habitat lacks the typical boulder strewn hillsides and flat alluvial plains predominate the landscape (Grandmaison 2008; Riedle et al. 2008). Tortoises can be found at elevations ranging from desert scrub communities at about 510 ft. all the way up to semi-desert grassland and interior chaparral communities at 5,300 ft. (Averill-Murray 2000).

SDTs rely on a variety of plant material for their diets, including residual and dried annual plants, fresh winter and summer annuals, perennial plant products and plant litter (Jennings 1993, Van Devender et al. 1993, McArthur et al. 1994, Oftedal 2002, Van Devender et al. 2002). SDTs have been documented to eat 199 species of plant including grasses, herbs, woody plants and succulents but the staple diet in the Arizona Uplands is primarily grasses, and desert vines and mallows that are also the preferred forage of livestock (Van Devender et al., 2002). Desert tortoises have occasionally been observed consuming bones and soil (Esque and Peters 1994, Averill-Murray et al. 2002a), and rarely to eat arthropods and vertebrate feces (Cordery et al. unpublished, Jennings 1993, Esque and Peters 1994).

Desert tortoises are one of the largest herbivores in their ecotype in terms of mass, but are restricted to browsing to less than 0.5 meters from the ground (Van Devender et al. 2002). Their opportunities for selective browsing are also restricted by seasonal and floristic considerations. In biseasonal areas of Arizona, the annual and grass floras of the winter-spring and summer monsoonal rainy seasons are markedly different. Between the two rainy seasons, consumption of dried plants by SDT is important particularly at the start of the monsoon season when summer annuals are not yet available and in drier years where light rainfall may provide opportunities for SDTs to hydrate but be insufficient to allow substantial plant growth (Van Devender et al. 2002). Within their range, the potential food plants SDTs may encounter vary greatly from east to west and north to south, and are also extremely variable from year to year (Oftedal 2002).

Desert tortoises use nitrogen from dietary protein to eliminate excess potassium because they are unable to excrete potassium via salt glands or to produce hyperosmotic urine (Oftedal 2002). Oftedal has demonstrated that Mojave desert tortoises are dependent upon the abundance of so called "high-PEP" winter annual plants. These are plants that have a high potassium excretory potential (PEP), an index that positively reflects the protein and water content and negatively reflects the potassium content of plants. In the Arizona Upland habitat of the SDT, the dietary importance of high-PEP winter annuals may be usurped by availability of summer plants, including C_4 grasses. The overgrazing-induced decline in C_4 grasses in parts of the Sonoran Desert may have adverse nutritional consequences for SDTs. The replacement of C_4 perennial grasses by invading annual C_3 grasses such as *Schismus* and *Bromus*, may also impact the nutritional status of tortoises given the lower protein and PEP content of these desert C_3 grasses (Oftedal 2002).

Activity and Behavior

Tortoise activity is seasonal in nature and the adults are largely inactive in the Sonoran Desert from mid-October to late February or early March. During this time, tortoises occupy winter hibernacula that include burrows, often excavated in loose soil or under vegetation, and other coversites including rock crevices (Averill-Murray 2000). In the Arizona Upland subdivision, boulders and natural rock cavities are the primary substrates for shelter sites, which are used both as hibernacula and for summer shelter. Tortoises use caliche caves as shelter more than other shelter types at the Florence Military Reservation in south central Arizona, and the absence of tortoises in washes with few caliche caves there suggests that availability of shelter sites strongly influences tortoise distribution (Riedle et al. 2008). Within the Lower Colorado River Valley subdivision, burrows are often incised in the caliche layer of cut-bank washes. Some differences exist between male and female hibernation habits and periods of activity (O'Conner et al. 2000) although Riedle et al. (2008) found no difference in coversite use by males and females. Female tortoises tend to hibernate in shallower shelters than do males, and are therefore exposed to more variable temperatures (Bailey et al. 1995, Lowe 1990). Because of this, females experience higher temperatures earlier in the spring and can emerge from hibernation as early as late February, whereas some males can remain inactive throughout the entire spring (Nagy and Medica 1986, Vaughn 1984).

Desert tortoises tend to use more than one den or burrow. During the nesting season, females use more burrows than males; later, in the mating season males tend to use more burrows than females (Bulova 1993).

Little data is available on the behavior and activity of hatchling and young tortoises in part because they are so difficult to study in the wild and only 12 had been observed on Sonoran Desert summer study plots between 1987 and 2002 (Averill-Murray et al. 2002). One of the 12 was observed foraging in November. Hatchlings may rely on use of preformed burrows such as rodent burrows (Germano et al. 2002) which makes it both difficult to identify their burrows and may place them at increased risk from trampling by domestic livestock, feral burros, and vehicles. It is unclear if their over-wintering behavior mimics that of the adults. In a study of Mojave desert tortoises at Fort Irwin, California hatchling activity was apparent in January with peak activity in February (Wilson et al. 1999). However, given the substantial ecological and genetic differences between them any extrapolation of the behavior of Mojave to Sonoran desert tortoises should be considered tentative (Germano et al. 2002). In depth studies of SDT hatchling biology are sorely needed.

Home Range and Long Distance Movement

Averill-Murray and Klug (2000) estimated minimum convex polygon (MCP) home ranges for 26- female and 11 male- telemetered SDTs at a site near Sugarloaf Mountain on the Tonto National Forest over a 1-3 year period. They found MCP home range areas were highly variable between individuals, both within years and overall. These Sugarloaf tortoises had a mean home range area of 4.1 ha (10.1 acres) in 1993 and 12.6 ha (31.1 acres) overall. In a recent study of 18 telemetered tortoises at the Florence Military Reservation study site which is typified by gently sloping alluvial fans bisected by steeply incised washes, estimated tortoise home range for males was 33.4 ha ± 28.96 (82.5 ± 71.6 acres), higher but not statistically significantly higher than the 17.8 ha ± 17.23 (44.0 ± 42.6 acres) for females (Riedle et al. 2008). Averill-Murray et al. (2002a) found that males had larger mean home ranges than females in a combined analysis of five SDT populations.

Sonoran desert tortoises are known to make long distance movements including between mountain ranges. Averill-Murray and Klug (2000) reported that two of their telemetered females tortoises (#14 and 55) made dramatically long-range movements, spanning up to 7 km in total. Female #55 embarked on a circuitous route of about 5 km across a braided floodplain and along a ridge of atypical tortoise habitat (that is, completely lacking large rocks or boulders) in October 1997; she finally hibernated in more typical, rocky habitat and occupied an area of 34.2 ha in 1998 before her transmitter failed. Female #14 moved approximately 3 km to the northwest in late summer 1998, hibernated, then moved about 4.5 km west in 1999 before hibernating again.

The carcass of a marked adult male was found two miles east of the Buck Mountain plot (Woodman et al 2002). It was identified as a 285 mm long male from the Hualapai Foothill plot, some 17 miles east of the carcass location. The tortoise was estimated to have died within the last year of an unknown cause. He was found twice in 1991 and once in 1996 when last seen. He was not found on the plot during the 2001 survey. Conceivably the tortoise could have been transported by a human but the carcass was well away from human habitation and was thought to have gotten here on his own. He was a large old tortoise and the field workers thought it doubtful that this was his first trip to this area.

Edwards et al (2004) report that a telemetered adult female tortoise made a long-distance movement of approximately 32 km from the Rincon Mountains to an adjacent mountain range (Santa Rita Mountains).

Clearly, SDTs may make long-distance movements and this holds important management implications. Averill-Murray and Klug (2000) suggested such movements may be interpreted as random wanderings, infrequent travels to known sources of biological needs, explorations, or they may be adaptations for genetic interchange with neighboring populations or for dispersal to other suitable areas. From estimates of historic gene flow among populations, Edwards et al. (2004) concluded that recovery of declining populations may rely heavily on the immigration of new individuals from adjacent mountain ranges.

Construction and development projects, such as canals, roads, housing, and agriculture, may form barriers or sources of mortality for individual tortoises that attempt to make such a movement. This may be true even if the project only occurs adjacent to or in between apparently suitable desert tortoise habitat, as in intermountain valleys generally unoccupied by tortoises in the Sonoran Desert (Averill-Murray and Klug 2000). Maintaining landscape connectivity should be the first objective in assuring the persistence of these populations (Edwards et al. 2004).

Physiology and Mating

Tortoise activity throughout the year is correlated with periods of moisture availability and forage abundance. If winter and spring precipitation is high, tortoise activity may also be high, as the animals will take advantage of spring annual forage. Tortoise activity decreases as the season moves into the summer drought in May and June (Averill-Murray 2000). During these times, tortoises can suffer a substantial amount of physiological stress. Animals utilize stored water in the urinary bladder to dilute excess dietary salts and metabolic wastes, but as drought progresses, body mass declines via cutaneous water loss (Minnich 1977, Nagy and Medica 1986, Peterson 1996a and 1996b, Duda et al. 1999, Averill-Murray 2000).

The summer monsoon season signals the beginning of the peak activity period for both male and female tortoises. Beginning in early August and extending through September, this period of rain is extremely important to tortoises as it allows them to drink, flush their bladders, re-hydrate and maximize their energy balance by intensive vegetation browsing (Duda et al. 1999, Averill-Murray 2000). Feeding initially begins with residual dried grasses and then progresses to other perennials and finally to fresh foliage and annual plants as they become available (Averill-Murray 2000). The monsoon season is also an important time for tortoise social interactions, as the animals tend to maximize their home range size during this period.

Frequent instances of male-male combat as well as mating have been observed during this time period (Averill-Murray 2000). Females will also begin laying eggs, fertilized by sperm stored from the previous year's mating, at the onset or during the summer monsoon season (Murray et al. 1996, Klug and Averill-Murray 1999, Averill-Murray and Klug 2000). Clutch sizes average about 5 eggs, but can range from 3-12 eggs/clutch (Averill-Murray 2000, Averill-Murray 2002b). The proportion of females that successfully reproduce in any given year is directly related to the amount of recent rainfall and the quantity and quality of available forage (Wallis et al. 1999, Averill-Murray and Klug 2000, Henen 2002). Females will lay their eggs in burrows with adequate soil development and will often remain at the nest to defend it against predators (Averill-Murray et al. 2002a).

Activity once again begins to wane after mid-October as the tortoises begin to retreat to their winter hibernacula. However, during mild winter periods, tortoises have been observed basking and browsing for forage much later, possibly to combat fungal growth, an infection caused by inactivity and extreme physiological stress (Nagy and Medica 1986, Averill-Murray 2000).

As mentioned above, females lay eggs during the summer rainy season that have been fertilized with sperm stored from matings in prior year. As a result, clutch size fluctuations and juvenile survivorship are dependent on the environmental conditions of both the current and the previous year's spring and summer periods. Low mating activity during the previous year due to drought or decreased forage availability could lead to decreased clutch sizes and/or a lower proportion of reproductive females even if the current year's precipitation and forage availability is favorable (Nagy and Medica 1986, Averill-Murray and Klug 2000, Klug and Averill-Murray 1999, Murray et al. 1996). Interestingly, female tortoises have also been observed ingesting calcium from direct mining activities, presumably to benefit the reproductive success of clutches (Marlow and Tollestrup 1982). However, given the myriad negative impacts to desert tortoises from mining (discussed below), this information should not be construed to imply that mining may benefit tortoises.

The sex and fitness of embryonic desert tortoises is determined by environmental conditions during incubation (Averill-Murray et al. 2002a). This phenomenon of environmental sex determination is common among different turtle genera and has been studied experimentally in Mojave desert tortoises from Las Vegas (Spotila et al. 1993, Lewis-Winkur and Winokur 1995, Rostal et al. 2002). Mainly male hatchlings were produced when desert tortoise eggs were incubated below 30.6˚C and mainly females above 32.8˚C with the pivotal temperature being 31.3˚C (Rostal et al. 2002). Hatchlings from eggs incubated at 28.1˚C and 30.6˚C were larger than hatchlings from eggs incubated at 32.8˚C and 35.3˚C. The latter temperature was lethal for 70% of eggs. The crucial step in embryonic development at which sex determination is temperature sensitive is stages 15 through 19-21 (Rostal et al. 2002) based on Yntema's 27 stage (i.e. stage 0 through 26) series (Yntema 1968). The threshold temperatures for both sex determination and fitness likely vary across the range of the desert tortoise (Averill-Murray et al. 2002a).

Tortoise hatchlings may either emerge in late summer or over-winter in the nest and emerge the following spring (Wilson et al. 1999, Averill-Murray 2000). Hatchlings are particularly vulnerable to predation and adverse environmental conditions as their carapaces are extremely soft when they leave the nest (Wilson et al 2001, Averill-Murray 2002). Average carapace length for emerging juvenile tortoises is 46 mm (1.8 in) and growth is most rapid during early development. Juvenile tortoise carapaces do not fully harden until approximately seven years of age, leaving juveniles exceptionally vulnerable to predation, especially by ravens (Boarman 2002). By the time individuals reach 5-10 years of age, they will typically be half their maximum size and growth rates begin to taper off (Murray and Klug 1996). Tortoises reach sexual maturity at 10-20 years and about 220 mm (8.6 in) carapace length, although there are some growth characteristics that vary geographically and by sex (Averill-Murray 2000). Tortoise populations north of the Gila River can reach maximum carapace lengths of 300 mm (11.8 in) while those south of the Gila River may only reach 250 mm (9.8 in) in length.

Sexual dimorphism in SDTs shows some population dependency (Averill-Murray 2000). Males in some populations may achieve greater average sizes than females, but females in other populations may exhibit faster growth rates than males.

V. TAXONOMY

The 1996 Policy Regarding the Recognition of Distinct Vertebrate Population Segments Under the Endangered Species Act considers 3 elements in determining the status of a DPS (USFWS 1996). These are: 1. Discreteness of the population segment in relation to the remainder of the species to which it belongs; 2. The significance of the population segment to the species to which it belongs; and, 3. The population segment's conservation status in relation to the Act's standards for listing (i.e., is the population segment, when treated as if it were a species, endangered or threatened?). As we explain below, the Sonoran desert tortoise clearly qualifies as a DPS.

Genetic and morphological studies have identified two major geographic assemblages of desert tortoise within the United States – a Mojave assemblage found north and west of the Colorado River and a Sonoran assemblage, found south and east of the river (McLuckie et al., 1999). Although the desert tortoise, *Gopherus agassizii*, is currently considered to comprise a single species, biologists have proposed that these two major assemblages are at least different sub-species (Lowe 1990) and may be distinct species (Murphy 2007).

Tortoise populations from the Sonoran Desert differ genetically (Lamb et al., 1989, Murphy et al., 2007), morphologically (Germano, 1993), and ecologically (Luckenbach, 1982) from tortoise populations in the Mojave Desert. Sonoran desert tortoises are geographically separated from most Mojave desert tortoise populations by the Grand Canyon and Colorado River. The STD therefore represents a distinct population segment (DPS) based on geographic separation, as described under USFWS policy (USFWS 1996). The combination of geographic separation, morphological and physiological differences in size and average lifespan, ecological separation in habitat and behavior, and mitochondrial DNA (mtDNA) polymorphisms has lead some authors to hypothesize that the Sonoran desert tortoise population constitutes a distinct species (Berry et al. 2002; Murphy et al. 2007). As such, the SDT is considered a DPS, as USFWS itself recognized in its 1990 rule listing the Mojave populations as threatened (USFWS 1990).

Analysis of mtDNA (Lamb et. al 1989) shows that across the entire range (i.e. including Mexico) desert tortoise populations form at least three genetically distinct assemblages. These include the Sonoran Desert population, the Mojave Desert population, and a Sinaloan population (found at the southern end of the range in Mexico) that may reflect geographic isolation imposed by the Colorado and Yaqui Rivers. These populations exhibit the *highest* degree of genetic polymorphisms of *any* tortoise species, and coupled with physiological and ecological data, the evidence unequivocally shows that these populations meet the requirements of a DPS and Evolutionarily Significant Unit (ESU) (Lamb et. al 1989, Walker and Avise 1998, Berry et al. 2002, Lamb and McLuckie 2002). Additionally, existing data on the social behavior of desert tortoises indicates significant variability in wild populations, including the existence of dominance hierarchies that make the success of interbreeding or possible relocation of individuals between ecologically distinct tortoise populations unlikely (Berry 1986, Berry et al. 2002).

Geographic Isolation

The Grand Canyon and Colorado River are effective barriers enforcing geographic isolation between the Mojave and Sonoran Desert populations of the desert tortoise within the U.S. To the north, the slopes of the Grand Canyon serve as an absolute barrier preventing emigration of either population. To the south and west, the Colorado River functions the same way.

Although today the Colorado River, with its modern impoundments and regular flow, prevents migration, in the geologic past fluctuations in flow rates and drought cycles probably would have allowed some limited dispersal and colonization (Lamb and McLuckie 2002). This may explain why a population of Mojave-type tortoises occurs in suitable habitat north of Kingman, Arizona. Based on the genetic data, a likely estimate of the time of divergence of the Mojave and Sonoran populations is five – six million years ago (Lamb et al. 1989, Lamb and McLuckie 2002). This date of divergence corresponds with a geologic flooding event known as the Bouse formation. This event flooded the inland areas from Yuma north to Nevada and is geographically congruent with the genetic break between the Mojave and Sonoran tortoise assemblages (Lamb et al. 1989, Lamb and McLuckie 2002).

Morphological and Physiological Characteristics

Germano (1993) found that Sonoran and Mojave tortoises were significantly different morphologically based on discriminant analysis of 32 shell measurements. Sonoran tortoises were narrower than Mojave tortoises, were less domed, and had shorter gulars. McLuckie et al found that Sonoran tortoises had a smaller plastron boundary, larger carapace width at junction of marginals four and five, larger carapace width at marginals three and four, and larger carapace diagonals and bridge width compared to Mojave tortoises (McLuckie et al., 1999). Curtin (2006) found that female but not male Sonoran tortoises were larger than Mojave tortoises and that male and female Sonoran tortoises were wider than their Mojave counterparts. She also found that for her sample, Sonoran females had significantly larger resorption core diameters (RCDs) in their humeri, ilia, and scapulae than West Mojave females, and that Sonoran male tortoises had significantly larger RCDs in their humeri and ilia. She proposes that larger RCDs in Sonoran tortoises are a potential biomechanical adaptation to locomotion on mountain slopes and rocky hills.

Desert tortoise life spans exceed 35 years in the Sonoran Desert (Germano 1992, 1994 & 1998, Averill-Murray 2002b) and may exceed 60 years (Germano et al., 2002). Life history traits of tortoises, such as slow growth, delayed sexual maturity and iteroparity require high adult survival rates to maintain viable populations. The viability of Western Mojave desert tortoises is most sensitive to survival of large females (Doak et al. 1994) and the same general pattern of survivorship is believed to contribute to population persistence in the Sonoran Desert (Averill-Murray et al. 2002b).

Ecological Divergence

Major ecological differences exist between Sonoran and Mojave desert tortoise populations, the result of the very different geologic and vegetative characteristics of the Mojave and Sonoran Deserts (Turner 1982a and 1982b).

High tortoise densities within the Mojave occur largely in intermountain valleys, where easily excavated soils provide for the construction of large, deep burrows (Bury et al. 1994, Averill-Murray et al. 2002a). In contrast, SDT populations of the highest densities occupy steep, rocky slopes and are often absent from the hot intermountain valleys (Averill-Murray et al. 2002a). Tortoises in the Sonoran Desert often utilize rock crevices or burrow underneath shrubs to find shelter. Local populations are smaller within the more rugged Sonoran landscape than in the Mojave (Averill-Murray 2002a). The SDT population on the Florence Military Reservation in south-central Arizona, which is typified by gently sloping alluvial fans bisected by steeply incised washes, was concentrated around incised washes with dense caliche caves suggesting that availability of shelter sites strongly influences SDT distribution at least at there and at similar sites (Riedle et al. 2008).

Precipitation is greater in the Sonoran Desert than in the Mojave Desert, and its amount and timing are on a gradient from north to south; as the frequency of precipitation increases to the south the amount falling in summer also increases (see Germano et al. 1994). The resulting summer annual vegetation provides an important forage source for SDT that is not as predictably available to Mojave desert tortoises (see section on community associations above).

Reproductive physiology also differs between Sonoran and Mojave populations of the desert tortoise. Whereas Sonoran females lay a maximum of one clutch per year, typically with five eggs (range 1-12 eggs/clutch), Mojave females can lay as many as three clutches per year with an average clutch size of 5-12 eggs (Wallis et al. 1999, Averill-Murray 2002b). These differences may make the SDT even more vulnerable to population declines than the federally protected Mojave desert tortoise, if rainfall continues to become less predictable among years, as expected under climate change and other models (see below).

Mojave desert tortoise females typically lay their eggs earlier (April-mid July) than do Sonoran females (early June-August) (Booth 1958, Averill-Murray 2002b). These significant reproductive differences are likely related to ecological differences between the two regions (Wisdom et al. 2000, Henen 2002). Averill-Murray and others speculate that Sonoran females employ the strategy of investing all their reproductive effort into a single clutch, prior to the onset of reliable summer rains, attempting to maximize juvenile survivorship by providing them access to abundant post-rain forage. The reproductive strategy employed by females in the Mojave populations is significantly different, with reproduction commencing at smaller body sizes and younger ages, and at higher clutch numbers, in order to maximize juvenile survivorship in the different condition of the Mojave Desert (Averill-Murray 2002b, Henen 2002).

Genetic Polymorphisms

Based on mtDNA analysis of restriction fragment polymorphisms, populations of *Gopherus agassizii* form at least three major genetic units, consisting of the Colorado and Mojave Deserts as a single unit (currently defined as the Mojave desert tortoise population by the USFWS), the Sonoran Desert Unit (from west-central Arizona to central Sonora, Mexico), and the southern Sonora and Sinaloa unit (entirely within Mexico, south of the Yaqui River) (Lamb et al. 1989, Lamb and McLuckie 2002). Recent detailed, genetic analysis of the Mojave population shows strong isolation by distance effects and clear delineation of DPS within the Mojave Desert population (Murphy et al 2007). A similar in depth study of SDT populations is warranted.

Lamb and McLuckie (2002) point out that the phylogeographic structure observed among the three major tortoise populations is striking, and may primarily be based on geographic isolation imposed by the Colorado and Yaqui Rivers. While the Mojave population exhibits several related genotypes, the Sonoran desert tortoise, located south and east of the Colorado River, is represented by a single genotype that maps closely to the Arizona Upland and Lower Colorado River Valley subdivisions of the Sonoran Desert Scrub community in which these tortoises are primarily found (Lamb et al. 1989, Lamb and McLuckie 2002).

The mtDNA analysis further demonstrates that the genetic differences found between the Mojave and SDTs are significantly greater than distance values reported for *any* other turtle species, and based on this level of genetic divergence it is likely that these population segments diverged over five million years ago with a common maternal ancestor dating to the late

Miocene Epoch (Walker and Avise 1998, Lamb and McLuckie 2002, McCord 2002, Van Devender 2002a). Indeed, this dating is well correlated with a geologic event of the time, an extensive inundation of the inland area from Yuma north to Nevada, which, combined with the northern barrier of the Grand Canyon, would have allowed complete population isolation to persist long enough for the evolution of the distinct populations we see today (Lamb and McLuckie 2002).

This hypothesis is bolstered by the presence of some geographically limited Mojave populations east of the Colorado in southwestern Arizona. Tortoise scientists had long observed that the populations of the Black Mountains exhibit behaviors more like Mojave than Sonoran desert tortoises, in particular occupying bajadas dominated by creosote bush (Lamb et al. 1996, Lamb and McLuckie 2002, Turner 1982a). If Mojave and Sonoran populations of the tortoise were not DPSs and these Mojavean-like tortoises were of mixed descent, then analysis of the Black Mountains population's mtDNA ought to reveal an *intermediate* mtDNA genotype. In fact, mtDNA analysis shows the Black Mountains populations possess distinctly Mojavean mtDNA genotypes (McLuckie et al. 1999, Lamb and McLuckie 2002). Lamb suggests historical dispersal, river meander, or human transport as possible mechanisms for the establishment of this isolated Mojave population east of the Colorado River.

The third population, extant in southern Sinaloa, exhibits significant genetic difference from both the Sonoran (4.2%) and Mojave (5.1%) populations in mtDNA restriction sites. Based on their extensive mtDNA studies within these three population segments, Lamb and McLuckie (2002) argue that the geographic distribution, genetic mtDNA divergence and concordant suites of characters indicate that the Mojave, Sonoran and Sinaloan tortoise populations, "clearly qualify as ESUs."

Murphy et al. 2007 confirmed the distinctive split in maternal lineages between the Mojave and Sonoran populations using defined mitochondrial DNA sequences. They conclude that the substantial sequence differentiation between Mojave and Sonoran (Arizona) populations is consistent with the hypothesis that *G. agassizii* consists of more than one species.

Based on the above discussion, it is clear that the Sonoran desert tortoise qualifies as a DPS. As we show herein, the Sonoran desert tortoise is in a state of severe decline. Petitioners are requesting federal listing of this DPS under the Endangered Species Act.

VI. DISTRIBUTION AND STATUS

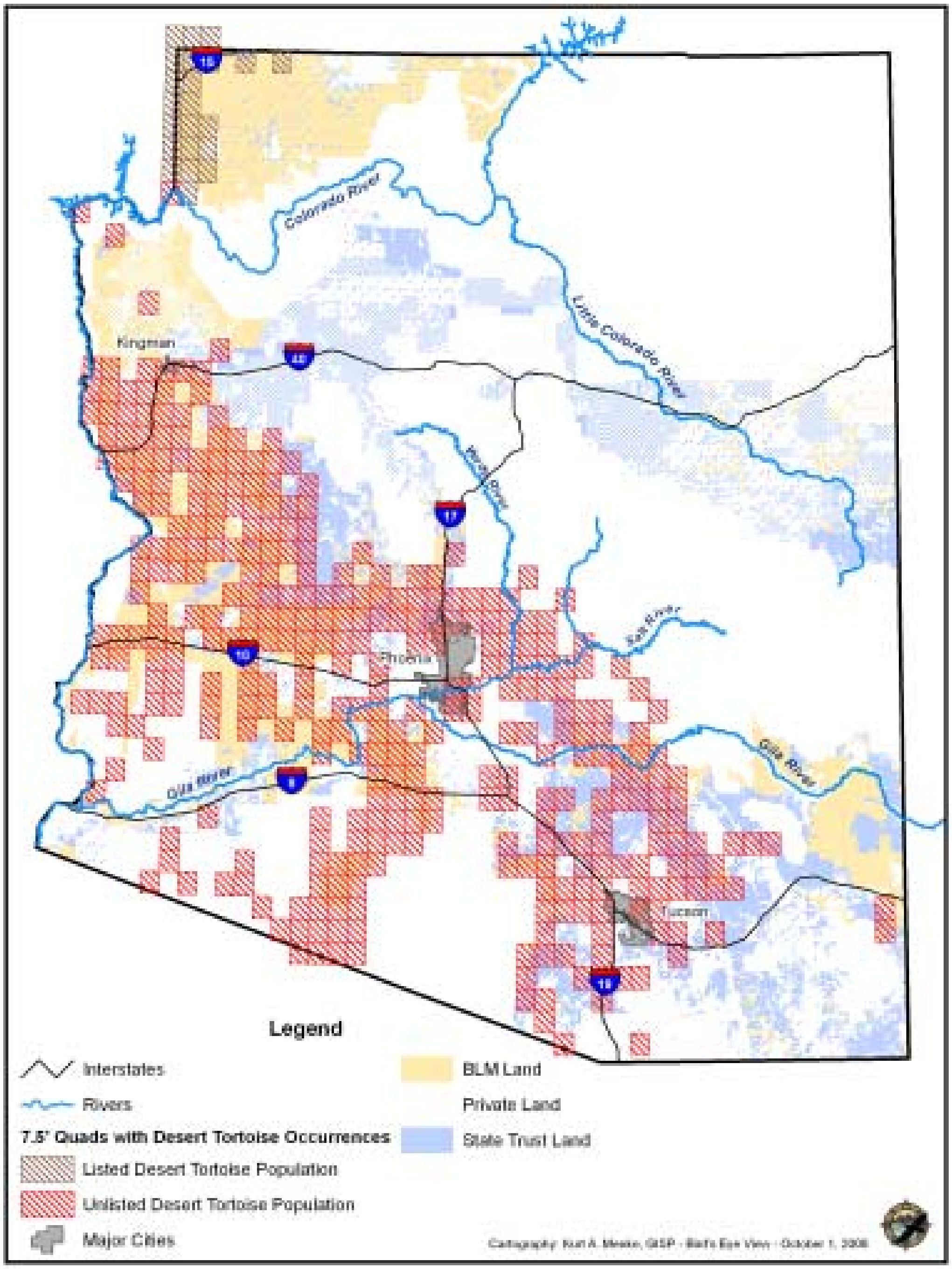

Figure 1. Distribution of known tortoise occurrences by 7.5' quadrangle with land status. Data from the Arizona Heritage Data Management System.

Figure 1 shows the distribution of the desert tortoise within Arizona, according to the Arizona Heritage Data Management System as of August 2008. The data represent USGS 7.5' quadrangles in which tortoises have been observed, with a total of 715 element occurrences for the Sonoran desert tortoise and 146 element occurrences for the Mojave desert tortoise for the period 1930-2004 (AZHDMS 2008).

For convenience, we have grouped the Arizona tortoises as "listed" or "unlisted" based on the USFWS decision to define the "listed" Mojave population geographically as all tortoises found north and west of the Colorado River. However, it is well established that the population in the Black Mountains north of Kingman consists largely of tortoises exhibiting Mojave genotype, phenotype, and habitat selection (McLuckie et al. 1999). Although those authors recommended that future management of the Black Mountain population emphasize protection of this unusual population, the population has remained unlisted. We therefore follow the USFWS lead and include the Black Mountain tortoise population under the SDT umbrella for the purposes of this petition.

Sonoran desert tortoises occur throughout southwestern Arizona in Mojave, La Paz, Yuma, Yavapai, Maricopa, Pinal, Gila, Pima, Santa Cruz, Graham and Cochise Counties (Figure 1). This widespread distribution occurs primarily on BLM lands, although a significant portion of desert tortoise habitat also occurs within state trust lands (Figure 1). Desert tortoise habitat is also found on the Tonto, Coronado and marginally on the Prescott National Forests (Murray and Schwalbe 1993). In 1976 and 1977, three tortoises were found in eastern Cochise County that may represent an outlying group or possibly were released captives (Hulse and Middendorf 1979).

The actual area of Sonoran desert tortoise habitat in Arizona has been estimated with varied results but is complicated by the tendency of SDT populations to be concentrated on discrete mountain ranges. In 1991, AGFD estimated there to be some 10,665 square miles (27,623 km^2) of potential Sonoran desert tortoise habitat in Arizona (USFWS 1991).

In 1988, the BLM developed habitat categorization guidelines as part of its range-wide management plan for the desert tortoise (Spang et al. 1988). Desert tortoise habitat was characterized into three types (Table 1). The distinction in habitat category was based on evaluation of four criteria (Table 1); 1) importance of habitat to maintaining viable populations, 2) resolvability of conflicts, 3) desert tortoise density, and 4) population status (stable, increasing or decreasing) (Spang et al. 1988). Criterion 1 is the most important criterion in determining which category a given parcel of land falls into.

Table 1. BLM Sonoran Desert Tortoise habitat category criteria (from AIDTT 1996)

	Category I Habitat	**Category II Habitat**	**Category III**
Category Goals	Maintain stable, viable populations and protect existing tortoise habitat values; increase populations, where possible	Maintain stable, viable populations and limit further declines in tortoise habitat values	Limit tortoise habitat and population declines to the extent possible by mitigating impacts
Criterion 1	Habitat Area essential to maintenance of large viable populations	Habitat Area may be essential to maintenance of viable populations	Habitat area not essential to maintenance of viable populations
Criterion 2	Conflicts resolvable	Most conflicts resolvable	Most conflicts not resolvable
Criterion 3	Medium to high density or low density contiguous with medium or high density	Medium to high density contiguous with medium or high density	Low to medium density not contiguous with medium or high density
Criterion 4	Increasing, stable or decreasing population	Stable or decreasing population	Stable or decreasing population

BLM's goal for category I and II lands were to maintain viable tortoise populations, while the agency's stated goal for category III lands was simply to limit population declines to the extent possible.

In 1990, the BLM published its "Strategy for Desert Tortoise Habitat Management on Public Lands In Arizona" which mapped tortoise habitat by category (BLM 1990). Category I lands comprised 10%, category II lands 36% and category III lands 54% of BLM categorized Sonoran desert tortoise habitat in Arizona (Table 2).

Table 2. BLM categorized desert tortoise habitat acreage by landowner.

Habitat Category	BLM	State Trust	Private	Other	Total
I	505,954	26,848	14,161	215,871	762,834 (10%)
II	2,011,728	245,011	188,217	234,628	2,679,584 (36%)
III	2,093,105	967,109	689,908	261,480	4,011,601 (54%)
Total	4,610,788 (62%)	1,238,968 (17%)	892,285 (12%)	711,979 (10%)*	7,454,020 (100%)

*Percentages may not total 100% due to rounding – note also that Averill-Murray 2000 gives slightly different numbers but of similar magnitude.

The total land area categorized by the BLM amounted to some 7,454,020 acres (11,646 square miles). Of this area, BLM manages 4.6 million acres or 62% of the Desert Tortoise habitat it categorized in Arizona in 1990 (Table 2). The amount of land categorized by BLM is larger than the total area of BLM administered lands because polygons were drawn within the boundaries of each field office and other lands not managed by BLM were included. Of the non-BLM administered lands, State trust lands comprise over 1.2 million acres, or just under 17% of the categorized habitat and privately held lands comprised another 892,000 acres, or 12% (Table 2). The remaining 10% of BLM categorized tortoise habitat occurs under a variety of jurisdictions. Of these, the most significant is the Department of Defense's Luke-Williams Range, which contains 546,117 acres of desert tortoise habitat. Four other entities manage most of the remaining BLM categorized tortoise habitat: Bureau of Reclamation, 47,931 acres; Arizona State Parks and Recreation Department, 35,114 acres; Military Reservations, 20,841 acres; and, Saguaro National Park: 16,752 acres.

Considerable amounts of habitat occur outside BLM's management areas. Estimates for tortoise habitat within the Coronado National Forest are approximately 250,000 acres, and within the Tonto National Forest as much as 400,000 acres. (Averill-Murray 2000).

In order to address the important question of desert tortoise conservation on public land, we estimated the habitat within these two forests as a function of the confirmed species occurrences on file with the Arizona Heritage Data Management System. By locating each occurrence to its corresponding 7.5 minute quad, we determined the overlap of quads with U.S. Forest Service (USFS) grazing allotment land as a general estimate of habitat within each forest (Figure 2).[2] Our habitat model indicated potential desert tortoise habitat of 849,683 acres for the Tonto and 239,343 acres for the Coronado (Figure 2).

Within the Coronado National Forest, tortoise habitat occurs largely along the western border where elevation changes shift community types from Sonoran desert scrub to more montane communities, and primarily within the Santa Catalina Ranger District (Turner and Brown 1982, Averill-Murray 2000). Within the Tonto National Forest, tortoise habitat occurs primarily along the southern and western borders of the forest in Maricopa and Gila Counties.

Outside of public lands, tribal lands including the Cocopah Reservation and Tohono O'odham Nation include significant SDT habitat. The three million-acre Tohono O'odham Nation contains at least 28 recorded occurrences of desert tortoises, and likely tens of thousands of acres of tortoise habitat (AZHDMS 2002).

Sonoran desert tortoises also occur in suitable habitat south of the border in Sonora, Mexico (Patterson 1982; Fritts and Jennings 1994; Germano et al. 1994). The tortoises occur in disjunct pockets in rocky habitat at middle elevations on the mainland. Tortoises also occur on

[2]This same method was used by the Tonto National Forest in 1993 to develop its Action Plan for desert tortoise management (TNF 1993).

Isla Tiburón in the Gulf of California. At one time, populations reached 65 tortoises/km^2 on Isla Tiburón (Reyes Osorio and Bury 1982), which is the highest density known among SDT populations. However, this population has experienced high mortality in recent years and has declined (Vaughn et al. 2003, Torres and Andrade 2005). In response to reports by the Seri Indians of high desert tortoise mortality on Isla Tiburón, a tortoise mortality survey was conducted at one island site in October 2001 and two mainland sites in October 2002. High and recent mortality was observed at all sites, indicating that tortoise die-offs are occurring beyond U.S. borders (Vaughn et al. 2003).

The southern range of the SDT population in Mexico may extend as far south as the Rio Yaqui. South of that river, the Sonoran desert tortoise is replaced by the morphologically and genetically distinct Sinoloan desert tortoise (Lamb et al. 1989).

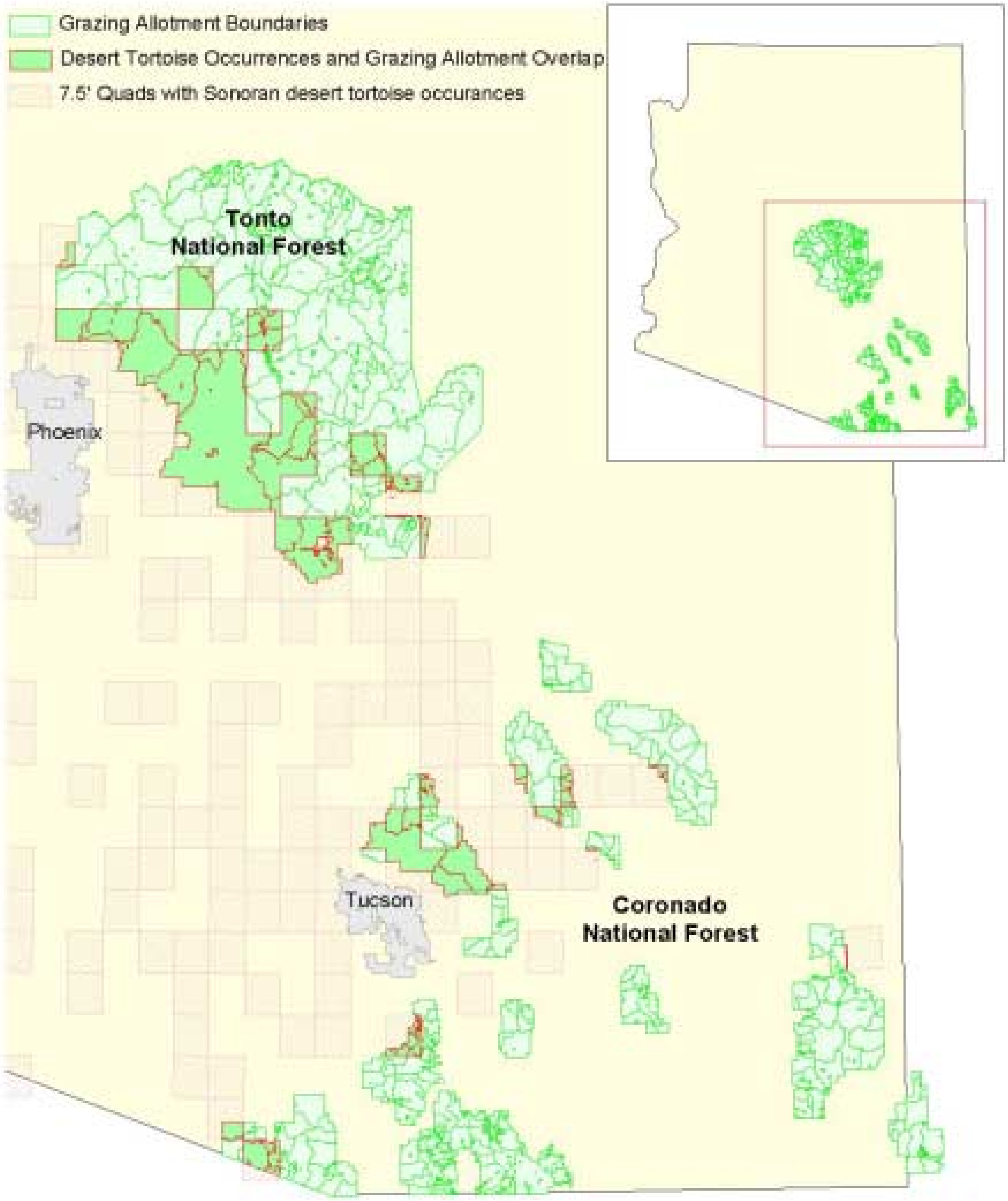

Figure 2. Potential desert tortoise habitat for eastern Arizona. The map illustrates the overlap of known desert tortoise occurrences, by USGS 7.5' quadrangle, with National Forest boundaries and grazing allotments on the Coronado and Tonto National Forests.

Table 3. Monitoring sites by agency. The table describes the monitoring conducted by year for each agency for the period 1987-2003. AZSLD – Arizona State Lands Department; BLM – Bureau of Land Management; BMGR – Barry M. Goldwater Range; OPNM – Organ Pipe Cactus National Monument; SNP – Saguaro National Park; TNF – Tonto National Forest. Data from Sites listed in bold type are analyzed in Boarman and Kristan (2008; Appendix 3)

Agency	Site	Habitat Category	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
AZSLD	**Granite Hills**	II				X	X	X	X	X				X					X				
	Little Ship Wash	III				X	X	X	X	X				X					X				
	Tortolita Mts.	-						X															
BLM	**Arrastra Mts.**	I	X										X					X				X	
	Bonanza Wash	I						X					X					X				X	
	Buck Mtns.	-																X			X		
	Eagletail Mts.	II	X			X	X	X	X	X				X					X				
	East Bajada	I				X			X	X			X					X					
	Harcuvar Mts.	I		X			X		X				X					X				X	
	Harquahala Mts.	I		X						X							X			X			
	Hualapai Foothills	II					X					X					X				X		
	Maricopa Mts.	I	X			X			X							X					X		
	New Water Mts.	II		X											X				X				
	San Pedro Valley	II				X	X	X			X						X			X			
	Santan Mts.	II				X	X																
	Tortilla Mts.	II						X				X					X						
	West Silverbell Mts.	I					X				X					X				X			
	Wickenburg Mts.	II					X									X				X			
BMGR	Sand Tank Mts.	II						X		X													
OPNM	Ajo Mtn. Drive	-										X											
	Quitobaquito Hills	-											X										
	Twin Peaks	-										X											
SNP	Rincon Mts.	-										X	X										
	Tucson Mts.	III										X	X										
TNF	**Four Peaks**	-						X			X						X						
	Mazatzal Mts.	-				X	X				X												

VII. POPULATION ABUNDANCE AND TRENDS

Monitoring

Monitoring of SDT populations has occurred sporadically at 26 permanent study plots in Arizona from the mid 1970's-2006 [Table 3]. Thirteen sites have been surveyed at least four times each. Wickenburg, New Water, Mazatzal Mountains, and Four Peaks were surveyed three times, and Buck Mountain only twice. Santan, Sand Tanks, Rincon, and Tucson Mountains were surveyed twice in the early to mid 1990s and have not been surveyed since. Tortolito Mountains, Ajo Mountain Drive, Quitobaquito Hills, and Twin Peaks have only been surveyed once each, and not since 1997. Most sites on Bureau of Land Management administered lands have been surveyed every three to five years since the mid to late 1990s.

Survey methodology has varied across sites and across years, as has survey effort. Questions regarding the usability of various survey methodologies for desert tortoises have been repeatedly raised (Luckenbach 1982, Berry 1984, Anderson et al. 1998, Freilich and LaRue 1998, Brown 2000, Freilich et al. 2000, Anderson et al. 2001). Assumptions implicit in the transect methodology, size and location of permanent plots, and observer dependence have contributed to significant scientific controversy as have wide variations in reported tortoise numbers from year to year attributed to rainfall fluctuations (Lukenbach 1982, Freilich and LaRue 1998, Brown 2000).

Boarman and Kristan (2008; Appendix 3) have undertaken a detailed review of the data from the seventeen study sites for which survey methodology was comparable, for which data sets were available for multiple time points, and which covered the period 1987 to 2006 which represents the time period since USFWS chose not to list the Sonoran desert tortoise population. Boarman and Kristan's analysis is most recent synthesis and analysis of study plot data and as such constitutes the best available science with respect to determining trends in Sonoran desert tortoise populations. Their complete study is incorporated into this petition as Appendix 3.

Table 3 lists 26 SDT study sites and the 6 agencies that manage the sites. The 17 study sites analyzed in Boarman and Kristan (2008) are indicated in bold type. An additional survey was conducted by the BLM in 2002 at Standard Wash (Walker and Wood 2002). The survey uncovered tortoise sign (old tortoise scat and an abandoned burrow) but no tortoises were observed within the 26.5 acres surveyed. This survey site is not designated as a permanent monitoring plot and is unlikely to receive the long-term monitoring necessary for it to add significantly to the understanding of desert tortoise ecology and population dynamics in the Sonoran Desert.

Abundance and Trends

Boarman and Kristan (2008) show that Sonoran desert tortoise populations have experienced statistically significant declines of 3.5% per year between 1987 and 2007 (see Appendix 3, Boarman and Kristan, 2008) on the 17 study plots they reviewed. This equates to an estimated 51% reduction in the number of adults and subadult tortoises since 1987. Trend determinations for individual study sites were compounded both by the small numbers of time points and by small study plot population sizes. However, four of the 17 monitored populations for which trend information is available experienced statistically significant ($p < 0.05$) declines in their populations, and a fifth showed a strong declining trend ($p \leq 0.1$) (Figure 3a). With respect to the latter statistic, we note that for purposes of determining trends in Mojave desert tortoise populations the Service is proposing to opt for the reduced confidence level of 10% (i.e. $p \leq 0.1$) in its draft revised recovery plan.

Boarman and Kristan (2008) were concerned that the significant overall declines may have been unduly influenced by one of the plots, Maricopa, which consisted of large numbers of animals, had several years of data, and showed a strong decline. They removed the Maricopa data and reran the analyses. The declines for adults alone (-1.14% per year) and adults and subadults combined (-0.92% per year) were smaller when Maricopa was removed, but remained statistically significant ($p \leq 0.05$) when differences in abundance among plots was accounted for. Because there was no reason to consider the decline in population size at Maricopa data to be anomalous, it was included in further analyses.

Figures 3a-d show available population estimates for tortoises on individual study plots. The estimated 51% reduction in the overall number of adults and subadults on study plots since 1987 is not regional but is occurring on study plots located throughout the SDT range in Arizona. High variation among years, low sample sizes, and small numbers of tortoises on most plots made trend estimates for some of the individual study plots difficult to support (Boarman and Kristan 2008). Their analyses indicate that SDT populations on study plots did not have identical rates of change, some were declining, others may have decreased but not statistically significantly so, while some were possibly stable or showed non-significant increases.

The East Bajada population experienced the largest declines of nearly 15% per year, which translates to almost 96% over 20 years (Boarman and Kristan 2008). This population experienced a large die-off of adults between 1997 and 2002 with many dead and live animals showing signs of cutaneous dyskeratosis (CD). A large proportion of adults (65%) showed signs of CD in 1997 before the population crashed. In 2005, there was some evidence of immigration, reproduction, and recruitment (Woodman et al. 2006). In addition to CD, the primary threats to this population are cattle grazing, burro activity, canine predation, and prolonged drought. This

Figure 3: Changes in Sonoran Desert Tortoise population estimates on study plots for 1987-2006.

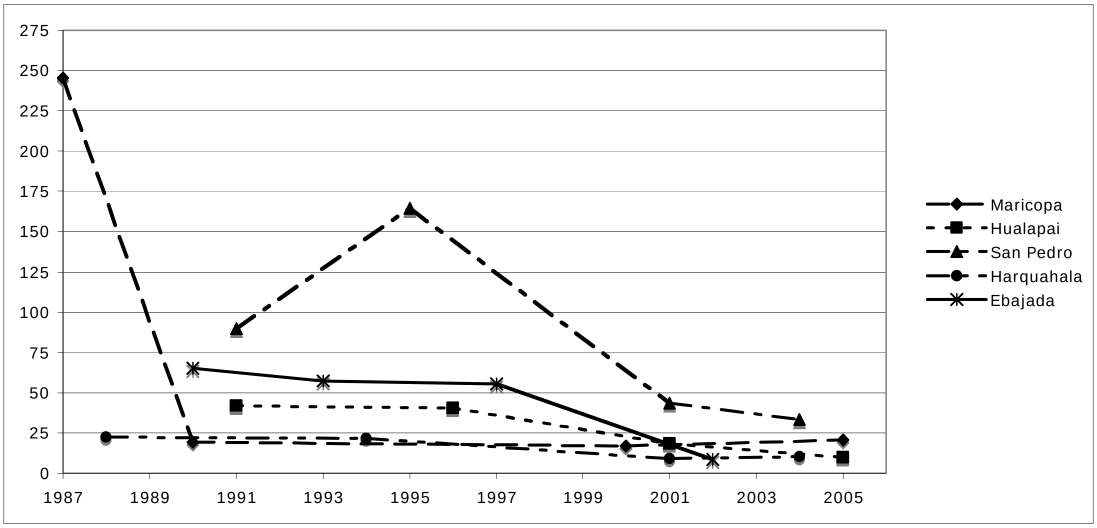

Figure 3a. Changes in population estimates for all tortoises on East Bajada, Harquahala, Hualapai, Maricopa, and San Pedro study plots. These plots show declining trends.

Figure 3b. Changes in population estimates for all tortoises on Buck Mountain and Four Peaks study plots. These plots have experienced declines, but the trends were not statistically significant (p = 0.634 – 0.441).

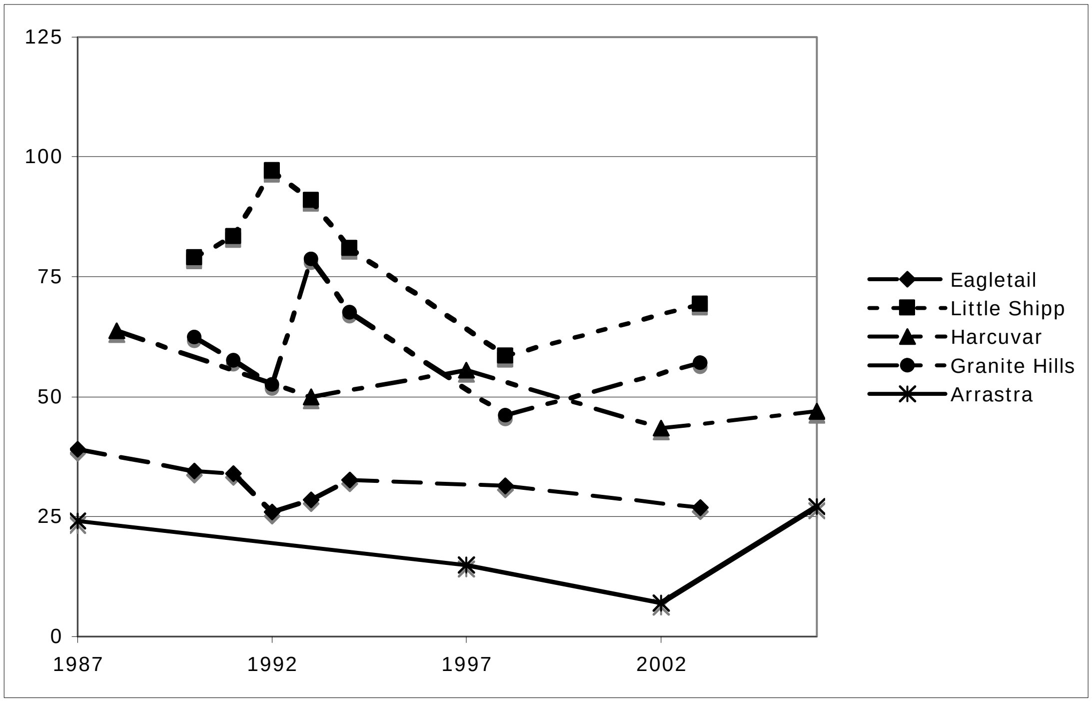

Figure 3c. Changes in population estimates for all tortoises on Eagletail, Little Shipp Wash, Harcuvar, Granite Hills and Arrastra study plots. These plots are probably close to stable or weakly declining (p = 0.537 – 0.780).

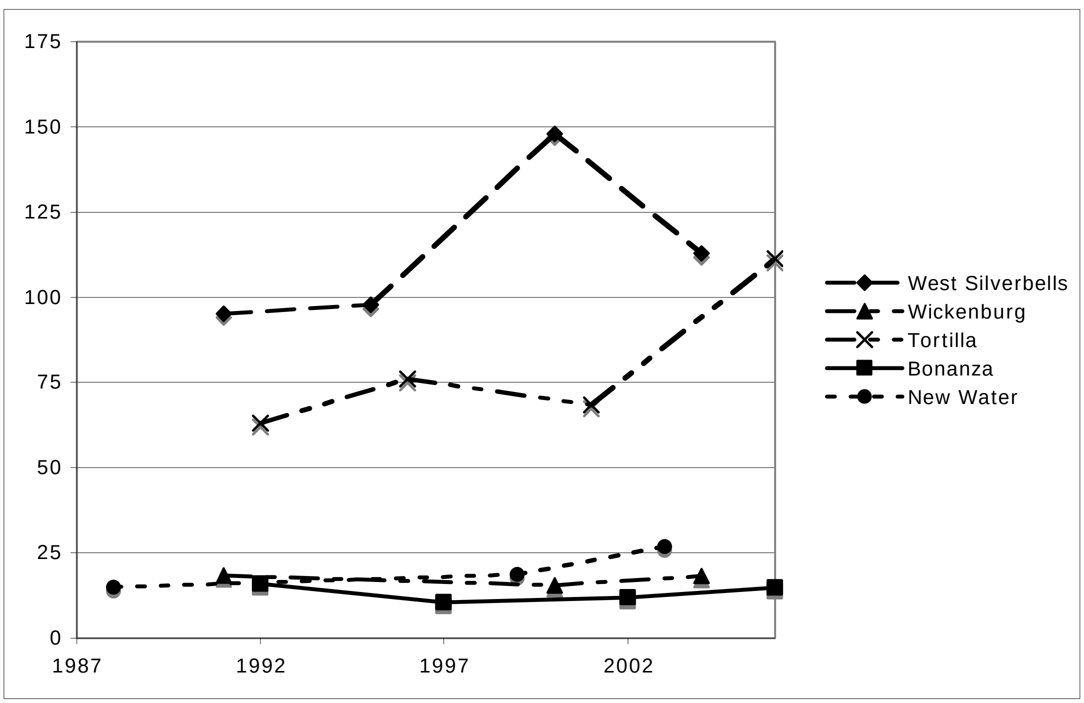

Figure 3d. Changes in population estimates for all tortoises on Bonanza, New Water, Tortilla, West Silverbells and Wickenberg study plots. These show no significant trends but may be stable or increasing (i.e., have slopes: -0.003 to +0.035, but very non-significant p values, 0.443 – 0.952).

population may be in a critical state and is susceptible to the hazards faced by small populations.

The Maricopa Mountains plot suffered severe statistically significant declines averaging 9.6% per year for adults and subadults. Overall, this population has experienced an 87% decline since monitoring commenced in 1987. The population experienced a major crash and may have since stabilized at a much lower level (approximately 10% of its former density). A large percentage of dead tortoises showed signs of cutaneous dyskeratosis and/or bone/scute abnormalities (Pete Woodman, pers. comm.). The plot is within a wilderness area designated in 1992 that itself lies in the Sonoran Desert National Monument. It currently experiences few human impacts other than livestock grazing (it lies within the active Big Horn cattle allotment).

Adults and subadults combined experienced a 10.27% ($p = 0.032$) annual decrease (89% in 20 years) on the Hualapai Foothills plot (Boarman and Kristan 2008). Adults alone also exhibited a significant decrease (10.23% annually, $p = 0.037$). The declines have been steady since 1990. The plot is within an active cattle allotment. The plot is in an area experiencing some urbanization and associated problems such as free-roaming dogs. There is evidence of URTD. Because of the nearby urbanization and associated problems, this population's future looks bleak.

The San Pedro Wash plot population experienced an average annual loss of 9.46% ($p = 0.052$) with an 86% decline over 20 years for adults and subadults combined (Boarman and Kristan 2008). There was an apparent increase between 1991 and 1995, but the 95% confidence intervals overlap widely so that the change more likely represents a sampling artifact rather than a demonstrable increase in the local tortoise population. Losses were greatest between the 1995 and 2004 surveys with the estimated abundance dropping by 73% (164 to 44 adults and subadults), but there is some evidence that the losses may be abating as few dead animals and several unmarked females were found on or near the site during the 2004 survey (Woodman et al. 2005). Human impacts in the area and access to the study population are relatively high and increasing (Woodman et al. 2005). URTD may be present in this population, but the incidence of CD is low. The study plot is within and active grazing allotment. Given low tortoise numbers, a high level of human impacts, and possible presence of disease, this population is decidedly at risk of extirpation in the near future.

The tortoise population on the Harquahala Mountains plot may have experienced declines (5.41% annually, 67% over 20 years for adults and 4.07% annually, 56% over 20 years for adults and subadults combined), but the data were not sufficient to yield significance ($p=0.164$, 0.195). Analysis of the adults only, yielded a downward trend of -7.19% annually ($p=0.101$). This population was quite small to begin with, which may explain the lack of statistical significance. The greatest reductions for adults plus subadults occurred between 2001 and 2004 surveys when the population may have suffered a 44% loss (from 18 to 10). The study site is within an active cattle allotment but there is little evidence that other human-associated impacts are causing its decline (Woodman et al. 2006). Its survival likely depends on the nature and extent of the more extended population of which the sampled tortoises are a subset, and there is some evidence that the surrounding population may be denser (Woodman et al. 2005). The population is especially susceptible to the demographic risks associated with small populations, depending on its level of connection to other populations.

None of the trends for the other individual plots approached statistical significance, however low sample sizes limit statistical power (Boarman and Kristan 2008). In the interest of maximizing ability to detect likely trends and avoid the pitfalls of missing biologically significant declines, Boarman and Kristan sought to identify apparent trends that lack lacked statistical significance. These trends are only hypotheses that have weak support and should not be taken as proof or strong evidence that the trends are real.

Two of these study plots yielded negative trends that were sufficiently great they may portend problems for the populations' future viability: Buck Mountains and Four Peaks (Figure 3b). These populations exhibited non-significant declines of 63 – 83% over the twenty-year period. However, given that these trends are not significant, additional years of study would be needed to confirm that these declines are not merely sampling artifacts.

The trends for Arrastra Mountain, Eagletail Mountains, Granite Hills, Harcuvar, and Little Shipp populations were close to zero, and p-values so high that they are likely stable or perhaps only slightly declining (Figure 3c). On these five plots, the negative trends may be real, but the low statistical power, resulting from low sample sizes (number of surveys) and number of animals found, may have precluded obtaining statistically significant results in spite of the large estimates of annual declines. The level of annual losses (1.25% to 2.45%), if real, is not trivial and indicates that the populations should be closely monitored and additional surveys performed to determine if these are the actual trends.

Arrastra Mountain showed an overall decline of 29% among adults plus subadults, but the numbers of animals was low and confidence intervals overlapped considerably (Boarman and Kristan 2008). Whereas there is little evidence of recent reproduction and recruitment, there is also little evidence of recent mortality. Grazing has been heavy on the plot, but the biggest threats are probably scarce habitat and small population size. The population may be stable, but should be watched because of its low abundance.

The Eagletail Mountains population, with a non-significant twenty-year trend of -30% ($p = 0.667$) for adults plus subadults, appears to be stable and may warrant little concern, beyond the current periodic monitoring program (Boarman and Kristan, 2008). The greatest potential threats are active grazing and some evidence of CD.

The Granite Hills population has been fairly erratic. The adults plus subadults exhibited a non-significant decline of 22% over 20 years (Boarman and Kristan, 2008). There has been little documented mortality, some evidence of reproduction, and little sign of disease. The study plot is within an active grazing allotment. Of great concern is its probable isolation from other populations (Woodman et al. 2004).

On the Harcuvar plot, the numbers of adults plus subadults may have declined by 29% (p = 0.660) over twenty years, and the trend suggests a relatively steady, but mild decrease (Boarman and Kristan, 2008). One animal in 2006 was suspected of having URTD, based on ELIZA test results, and a relatively high level of documented mortality between 2002 and 2006 could be cause for alarm. Harcuver is within an active cattle allotment.

The remaining plots, Bonanza, New Water Mountain, Tortilla Mountains, West Silver Bell Mountains, and Wickenburg, showed fluctuations and some increases although trends never approached statistical significance.

Bonanza Wash was considered of great concern in 1992, but since then the evidence of high losses has abated, there is little evidence of disease or mortality, and some indication of immigration from outlying areas (Woodman et al. 2007). However, the occurrence of heavy livestock grazing and moderately high human access coupled with very low tortoise abundance warrants possible concern for the population (Boarman and Kristan 2008).

The New Water Mountains population estimates suggest a strongly increasing trend (102% over 20 years for adults plus subadults). The lack of statistical significance for this trend may be because there are only three surveys or because the total number of tortoises on the plot is quite low (Boarman and Kristan 2008). There is a low level of anthropogenic threat and evidence of mortality is fairly inconsequential. The study site is within a grazing allotment although cattle use of the plot seems slight. Unfortunately, 27% of the population showed some signs that were consistent with URTD and 23% had some evidence of CD. Therefore, the stable or increasing numbers and low human impacts suggest low risk for the population, but the overall low numbers and high level of disease signs are both causes for alarm.

At Tortilla Mountains, the estimated tortoise population size has increased nearly every year it was surveyed (with a slight dip in 2001, well within the standard error range): adults plus subadults may have exhibited a 96% increase over 20 years and adults 56% (Boarman and Kristan, 2008). There is evidence of reproduction and recruitment and abundance is high. However, in 2006, one tortoise tested positive for URTD, and another was suspect. Livestock grazing, dispersed mining and vehicle access are considered ongoing threats to the tortoise population in the area where this study plot is located, and these could be acting as a significant stressor to an otherwise healthy tortoise population. Consequently, this tortoise subpopulation should be closely monitored.

The West Silverbell Mountains population has the highest number of tortoises of any plot, and estimates show a positive (upward) slope (Boarman and Kristan 2008). Adults plus subadult populations are estimated to have risen by 56% over 20 years and adults alone by 85%. However, estimates from 2004 are 24% lower than 2000, but not significantly different. Whether this represents the beginning of a downward trend, rather than sampling variation, should be re-evaluated after the next survey, scheduled for 2008. There is very little evidence of tortoise disease in the West Silverbell study plot population and anthropogenic threats are considered low. However, the study plot is within a grazing allotment and cattle use the site.

Both recent tortoise reproduction and recruitment have been documented. Consequently, this plot's population may be relatively secure especially with implementation of more appropriate management.

There has been little mortality on the Wickenburg Mountains plot and the population appears to be declining, but larger sample sizes may increase statistical power to detect a population change (Wickenburg Mountains only had three surveys) or increase confidence that the population is stable (Boarman and Kristan, 2008). There is considerable livestock grazing and small scale, dispersed mining at Wickenburg Mountains. However, no disease signs have been seen and evidence of recent tortoise reproduction suggest that this population may be healthy and perhaps relatively stable. However, this plot has one of the lowest overall abundances of tortoises of all Arizona study plots analyzed, which makes it much more difficult to detect an apparent trend and increases its risk of extinction due to stochastic events.

In conclusion, there is strong, statistically significant evidence of a 3.52 % decline per year in the adult and subadult and 3.64% decline in the adult tortoise populations on the 17 study plots evaluated ($p < 0.005$) (Boarman and Kristan, 2008). The 3.52% annual decline represents an overall reduction of 51% in the adult and subadult populations represented by the 17 study plots over the 20 years that suitable data have been collected. It is clear that SDT populations are experiencing a widespread population decline. If these declines continue at their current pace, local extirpations will soon occur. Immediate steps are needed to reduce the combination of threats faced by the SDT or they will face local extirpation and eventual extinction.

VIII. THREATS

> "*Because of the limited nature of the populations and habitat, Sonoran Desert tortoises are particularly vulnerable to human activities. Populations and habitat have been lost to expansion of urban areas and to encroachment of uses such as recreation, roads, and energy related rights-of-way. Grazing, mining, and fire also adversely affect some areas.*" (BLM 1988).

Many factors may cause destabilizing declines in animal populations, and these factors are considered threats. Some threats, such as disease or predation, directly remove tortoises from a population. Other threats act in a more indirect way, such as by reducing the quality or quantity of nutritious forage, increasing conditions that weaken individuals, producing toxicants that diminish an animal's life span, or by increasing fire risks due to changes in vegetation. While drought, flooding, and predation are often considered "natural threats" in contrast to human-associated impacts from vehicles, poaching, and livestock grazing, climatic conditions are also changing through anthropogenic activity and the number of predatory species such as ravens and coyotes is also increasing through human agency. Often "natural" threats are exacerbated or facilitated by the activities of humans, and act synergistically with anthropogenic threats.

Desert tortoise populations are affected by a myriad of threats, the complexity of which makes it difficult to isolate one or a few as being the primary threats to their populations (Boarman 2002, Tracy et al. 2005). There are little data available on the severity of each possible threat to tortoise populations and virtually none on the interactions among the multiple threats tortoises are facing. We have summarized known threats associated with the 17 study plots analyzed by Boarman and Kristan (2008) in Appendix 1. These include livestock grazing, mining, roads, hunting/shooting, urbanization, domestic dogs, feral burros, OHV, trash, fire history, predators and signs of disease.

Much of the evidence on how individual human activities affect tortoises comes from studies of the Mojave rather than the Sonoran population. There are important differences between tortoises from the two deserts and there are clear similarities too. Applying findings from one desert to the other should be valid so long as these differences are recognized.

We review below the five ESA listing criteria and show that SDTs meet at least four of the five criteria. This DPS therefore warrants listing under the ESA.

(1) PRESENT AND THREATENED DESTRUCTION, MODIFICATION, OR CURTAILMENT OF RANGE

Livestock Grazing

Livestock grazing within BLM categorized desert tortoise habitat is extremely widespread and occurs on 273 BLM allotments covering almost six million acres, or 78% of BLM managed SDT habitat (Table 4). Grazing has occurred on 16 of the 17 BLM/AGFD tortoise study plots. Livestock use of USFS land within potential desert tortoise habitat is equally widespread. As described above, we utilized a habitat model derived from Arizona Heritage Data Management System species occurrences by 7.5' quad, to estimate the acreage of habitat within the Coronado and Tonto National Forests and to determine the overlap of potential desert tortoise habitat with grazing allotments (see Figure 2 above). Our results indicated that grazing occurs on 83 allotments covering 938,000 acres, or 86% of the potential desert tortoise habitat on USFS land (see Table 6 below).

Table 4. Summary of grazing allotment acreage within BLM designated desert tortoise habitat.

Habitat Category	Number of Allotments*	Allotment Acreage within Habitat	Habitat Category Acreage	Percentage
I	50	543,412	762,834	71%
II	172	2,387,766	2,679,584	89%
III	206	2,880,698	4,011,601	72%
TOTAL	**273**	**5,811,876**	**7,454,020**	**78%**

*allotment numbers do not total due to overlap of allotments with habitat categories.

The threats posed to desert tortoises by livestock on public lands are numerous. Livestock compete directly for forage, trample vegetation, alter plant community structure, introduce and enhance establishment of exotic plants, enhance probability and intensity of fires, are known to damage tortoise burrows and other cover sites, and alter desert tortoise behavior (Berry 1978, Grover and DeFalco 1995, Avery 1997, Averill-Murray 2000, Boarman 2002, Esque et al. 2002, Grandmaison 2008). In addition, the presence of livestock and associated range improvements may facilitate increased numbers of predatory species such ravens.

Direct competition between livestock and Mojave tortoises for food plants has been documented (Tracy 1996, Avery 1998). Because of the enormous differences in size and energy requirements of livestock, the competition is likely to be heavily asymmetric, with cattle affecting the tortoise populations, but probably not the converse (Boarman 2002). Three conditions must be met for asymmetric competition to be established: overlap in use of some resource (e.g., food), the resource must somehow limit or constrain one or both species in question, and use of the resource by one species must negatively affect the other species (see Boarman 2002). Avery (1998) showed an overlap of 38% of cattle and tortoise diet in early spring and a 16% overlap in late spring. Tortoise foraging was altered in areas where both animals foraged. For example, in an exclosure ungrazed by cattle in late spring, herbaceous perennials comprised 91% of tortoises' diet (Avery 1998). In contrast, tortoises' diet on grazed plots shifted dramatically to 59% annual grasses and only 21% herbaceous perennials (Avery 1998). Availability of forage items preferred by tortoises, such as desert dandelion (*Malacothrix glabrata*), was significantly higher in the cattle exclosure than on the grazed plots. Consequently, "…in the exclosure, tortoises preferred desert dandelion, whereas in the grazed areas, they ate primarily the exotic grass, splitgrass (*Schismus barbatus*)" (Avery 1998).

Tortoises consuming primarily splitgrass "have been shown to be put into negative water and nitrogen balance, which could increase mortality, particularly during periods of extended drought" (Avery 1998). It is also known that low nitrogen intake reduces a female's reproductive output (Henen 1997). In years of low annual productivity, female tortoises lay fewer eggs. In a separate study, cattle grazing reduced availability of preferred tortoise forage abundance to the point of causing fewer eggs to be laid than in a normal clutch (Tracy 1996). Tracy (1996) concluded, "…in low rain years, cattle may remove enough forage to reduce tortoise reproductive output, thus competition occurs in those years."

The BLM has estimated that a single adult male tortoise would require up to 12 lbs. of forage per year. Thus, at population densities of 50 tortoises per square mile, up to 600 pounds of forage per square mile would be required to sustain a viable tortoise population (BLM 1991). This estimate does not take into account spatial availability, palatability, or nutritional quality, so it is more likely that the actual pounds of forage per square mile necessary to support a viable population of tortoises is as much as five times that number (BLM 1991). Estimates of current livestock grazing intensity in the western U.S. are in excess of 280 million Animal Unit Months (AUMs) (Grover and DeFalco 1995). The BLM typically bases an AUM on monthly forage consumption by a cow at about 800 lbs of forage (Carter 2008).

Burrows are extremely important to tortoises as refuges from temperature extremes and predators, and females frequently excavate their nests and lay their eggs within a burrow or burrow apron. Cattle occasionally collapse burrows rendering them unusable by tortoises and potentially entrapping tortoises inside (Esque unpubl.). On at least two occasions, radio-transmittered tortoises were mortally wounded when cattle trampled their burrows (Coffeen unpublished observations, cited in USFWS 1994b) which suggests that trampling of tortoises in their burrows by cattle is more common than is assumed. Avery (1997) found significantly more collapsed burrows in study plots where grazing occurred than in plots within a cattle exclosure. In addition, the tortoises (which are diurnal) spent more nights outside of burrows in the grazed areas than in the ungrazed area. Grandmaison (2008) found that SDTs selected burrow sites within their home range that were characterized by a higher percentage of canopy cover and less cattle activity. Burrow use also varies seasonally, and by sex and age class. During the nesting season, females use more burrows than males; later, in the mating season males tend to use more burrows than females (Bulova, 1993). Hatchling and juvenile tortoises select rodent burrows or dig their own superficial burrow with an average length of only 0.5 meters (Wilson et al., 1999) and may be more susceptible to trampling.

Livestock degrade habitat quality for a large suite of desert species, and the desert tortoise is among them. The ground becomes more compacted and less water percolates into the soil as a result of heavy grazing (Rauzi and Smith 1973, Avery 1998). Soil temperature also increases where vegetation has been removed (Luke et al. 1991, Hillard and Tracy 1997) and soil temperature affects sex determination in tortoises (Spotilla et al. 1994). Decreases in annual and perennial grasses, and an increase in less palatable shrubs and cacti, are well-documented effects of livestock grazing (Berry 1978, Bostick 1990, BLM 1991b, USFWS 1992, Fleischner 1994, Oldemeyer 1994, Grover and DeFalco 1995, Kazmaier et al. 2000). Tortoise growth and fecundity are highly correlated to vegetation production, both within the current year and as a result of residual vegetation from the previous year’s growth (Murray and Klug 1996, Averill-Murray 2000). Alterations in the plant community may have drastic effects on tortoise reproduction.

Additionally, long-term livestock grazing may modify vegetation composition (Humphrey 1958, Humphrey 1987, Durfee 1988, Waller and Micucci 1997, Avery 1998) and facilitate the proliferation of exotic plant species (Mack 1981, Jackson 1985, Brooks 1995). The introduction of non-natives has played a key role in the modification of historic fire regimes (see below) (BLM 1991, Grover and DeFalco 1995, Brooks et al. 1999, Alford 2001, Esque 2002 and 2003). A recent analysis of micro-habitat selection in Sonoran desert tortoises indicates that the tortoises selected areas within their home range that were characterized by a higher percentage of canopy cover, less cattle activity, and closer proximity to roads and washes (Grandmaison, 2008).

An often-hypothesized benefit of cattle grazing for tortoises, namely the opportunity to eat cow dung, has no empirical support. In a nonscientific article, Bostick (1990) asserted that cow dung is an important source of protein for tortoises. Both Avery (1998) and Esque (1994) studied tortoise foraging in areas where cattle also grazed. Avery (1998) recorded only 107 out of over 30,000 bites were of cow dung (0.3 of 1%). Esque also recorded over 30,000 bites by tortoises, and none of them were of dung. Furthermore, in a laboratory study of the nutritional quality of tortoise forage, Allen (1999) reported that cow dung was of very low quality and that most tortoises refused to eat cow dung even when it was the only food available.

Livestock grazing act may act synergistically with other threats. Relative drought conditions may prompt cattle to wander up to higher elevations and into important SDT habitat at the very time when environmental conditions place tortoises at increased risk. Stress from competition and habitat impacts is of particular concern. Many of the SDT populations show evidence of disease and stress may induce immunosuppression (Brown et al. 1994).

Agency documents frequently cite the claim that because SDTs prefer rocky slopes they are less impacted by livestock grazing compared to their Mojave cousins (see for example USFWS 1991). However, this is both over simplistic and incorrect. In some areas, SDTs do occupy lower lying areas that may be more heavily grazed by livestock, and to move between ranges certainly requires that tortoises pass through the valleys. Cattle do graze rocky slopes. As we document in Appendix I, 16 of 17 study plots are in grazed or historically grazed allotments. The various study site reports documented the actual presence of cattle or heavy sign and use during surveys on 9 of the plots. In a recent study of perennial grasses on the Sonoran Desert National Monument the authors report "we found several notable examples of cattle grazing well up on the rocky slopes, and in some cases on the very tops of the highest mountains. We observed both live and dead cattle in the mountains of the study area. Some of the plots that we established in 2003 in the mountain areas had been impacted by cattle grazing. One of these plots showed signs of significant additional impact between our fall 2005 and spring 2006 visits" (Morrison and Smith 2006). They had found no significant sign of cattle grazing above the desert flats and bajada surfaces in 2002, 2003 and 2004. Clearly then, data from multiple sources confirm that cattle use important lower elevation and upland SDT habitat.

Table 5. Summary of BLM grazing allotments and NEPA compliance. Source: BLM NEPA documents.

Habitat Category	Number of Allotments*	Allotments with NEPA Completed*	Percentage Of Allotments with NEPA
I	50	15	30%
II	172	19	11%
III	206	19	9%
TOTAL	**273**	**29**	**11%**

*allotment numbers do not total due to overlap of allotments with habitat categories.

Compounding the physical impact of livestock grazing on desert tortoise habitat, the regulation and enforcement of livestock industry practices on public land is a serious problem. A failure to adhere to the requirements of the National Environmental Policy Act (NEPA) is a particularly widespread problem, both within the BLM and USFS (Tables 5 and 6).

The NEPA process requires federal agencies to evaluate the proposed number of permitted cattle, season of use and other relevant factors, typically within an Environmental Assessment (EA) to determine if there is likely to be adverse environmental effects associated with permit issuance. Each EA must consider a range of alternatives to the proposed action, assess the relationship between short-term use and long-term productivity, and determine if any irreversible and irretrievable loss of resources, including sensitive species such as the desert tortoise, are likely to occur.

Table 6. Summary of USFS grazing allotments and NEPA compliance within potential desert tortoise habitat. Source: USFS NEPA documents.

Forest	Number of Allotments*	Allotments with NEPA Completed	Allotments with draft EA completed	Active Allotment Acreage within Potential Habitat*	Total Forest Service Potential Habitat Acreage	Percentage of Habitat in Use
Tonto	43	0	8	760,368	849,683	89%
Coronado	40	0	7	177,859	239,343	74%
TOTAL	**83**	**0**	**15**	**938,227**	**1,089,026**	**86%**

As evidenced by the data in Tables 5 and 6, both the BLM and USFS are largely failing to meet the requirements of NEPA for allotments within the potential habitat of desert tortoises. As of 2005, BLM had completed NEPA analyses for just 30% of the allotments within Category I habitat, for which the agency has pledged to “maintain viable populations”. In total, only 11% of the allotments within BLM classified desert tortoise habitat had completed the NEPA process (Table 5). USFS has not performed much better, completing NEPA for just 18% of the allotments within potential desert tortoise habitat (Table 6).

By their failure to conduct adequate NEPA in SDT habitat, USFS and BLM prevent the public from learning the true impacts of grazing permit renewal, fail to consider the best scientific information to ascertain the threat to SDT's, and fail to provide adequate mitigation measures – such as grazing exclosures, reduction of grazing, or termination of grazing – that could help protect SDT populations from the threat of livestock grazing.

Urbanization and Development

Urbanization and development impacts have increased dramatically in the Sonoran desert throughout Arizona since the 1990 final rule listing the Mojave population and the USFWS's 1991 decision that SDTs did not warrant listing. The impacts of urbanization and associated habitat loss and degradation have also impacted gene flow and thus the long term the viability of many SDT populations in Arizona (Edwards et al., 2004).

The impacts of urbanization and developments expand well beyond, both spatially and temporally, the direct construction activities necessary to build the developments. They include permanent loss and degradation of habitat, habitat fragmentation, restriction of gene flow, restriction of recolonization, the introduction, facilitation, and proliferation of many potentially harmful human activities, disruption of tortoise behavior, and road kills, to name a few. Urbanization increases predation by pets, collection by individuals, frequency of vehicular-caused mortality, and the introduction of disease (Averill-Murray and Swan 2002). Urbanization provides resources to subsidized predators, like ravens and coyotes, thereby increasing the number of animals that may find and eat the tortoises (Kristan and Boarman 2002). Long-distance movement of tortoises, reported by Averill-Murray and Klug (2000) and which may be important for maintaining genetically diverse populations of tortoises, is inhibited or altogether prevented by high levels of habitat fragmentation due to urban development (Gibbons 1986, Averill Murray and Klug 2000, Edward et al, 2004). The increase in development and urban sprawl, new roads, and increased traffic on established roads, further fragments populations, which are already highly fragmented as a consequence of SDT preference for steep, rocky habitat (Edwards et al. 2004). Fragmented populations suffer greater extinction rates due to the classic problems faced by small populations including demographic stochasticity and catastrophic events.

Urbanization and Private Development

Private land development impacts desert tortoise habitat on both private lands as well as adjacent federal lands, including those managed by BLM, USFS, NPS, and State Parks (AIDTT 2000, Averill-Murray and Swan 2002). Additionally, private development occurring within inholdings of federal and state lands fragments and degrades habitat that is otherwise protected or natural in character (Averill-Murray and Klug 2000, Oliva et. al 2004). Recent studies indicate that fragmentation and degradation of habitat within the Sonoran desert tortoise range is increasing dramatically.

This problem is seen vividly on BLM lands. The BLM has designated almost 470,000 acres of land as Areas of Critical Environmental Concern (ACEC) with specific directives to be managed as desert tortoise habitat: the Black Mountains Ecosystem Management Area, the White-Margined Penstemon ACEC, the McCracken Desert Tortoise ACEC, and the Poachie Desert Tortoise ACEC (Oliva et al. 2004). Additionally, the agency has designated three other large ACECs within BLM categorized desert tortoise habitat: the 64,000-acre Three Rivers Riparian ACEC, the 22,000-acre Burro Creek ACEC, and the 9,600-Coffeepot Mountain ACEC. Despite these bold conservation initiatives by the BLM, these ACECs also contain some of the largest acreages of in-holdings in the Four-Corners states (Oliva et al. 2004). In total, these eight ACECs contain 82,444 acres of inholdings, 64% of which are privately owned, and 87% of which are desert tortoise habitat (Table 7).

Table 7 indicates the potential development danger for tortoise habitat within the BLM ACECs. Five of these tortoise reserves face a significant danger of habitat loss and fragmentation from development: Black Mountains, Burro Creek, McCracken, Three Rivers, and White-Margined Penstemon ACECs. Particularly troublesome is the degree to which Category I habitat is privately held within the McCracken Desert Tortoise ACEC (almost 9,000 acres, or 34%), as well as the amount of privately held Category II habitat within the Three Rivers and White-Margined Penstemon ACECs (over 2,000 acres and almost 15,000 acres, respectively).

For at least one of these ACECs, the danger has become a reality. The White-Margined Penstemon ACEC, administered by the Kingman Field Office of the Arizona BLM, is among the largest ACECs in the southwest and contains almost 17,000 acres of inholdings, over 14,000-acres of which is Category II desert tortoise habitat. Despite the BLM's obligation to maintain desert tortoise populations within Category I and II habitat, private owners are free to develop their inholdings so long as the Sonoran desert tortoise is not afforded protection under the ESA. As of 2003, the White-Margined Penstemon ACEC was being surrounded by and subsumed within a 150,000-acre subdivision named Stagecoach Trails containing over 3,000 individual lots. Much of the privately held desert tortoise habitat within this ACEC has or is is being developed, and the remainder of federally held habitat has been severely fragmented (Table 7 and Figure 4). Given rampant urbanization around nearby recreational areas such as Lake Havasu, it is very likely that similar development problems will plague many of the desert tortoise ACECs listed in Table 7.

Table 7. BLM ACECs with significant desert tortoise habitat, and acreages of private, state and federal inholdings. The Table illustrates the potential development threat to desert tortoise habitat on BLM lands in Arizona.

BLM ACEC / Habitat Category	Tortoise Habitat Inholding Acreage	Total Tortoise Habitat Acreage	Habitat Overlap with Inholdings	Private Acreage	State Acreage	Federal Acreage
Black Mountains						
I	157	157	100%	142	15	0
II	0	2,932	n/a	0	0	0
III	10,663	59,089	18%	9,601	1,061	<1.0
Total	**10,820**	**62,178**	**17.4%**	**9,743**	**1,076**	**<1%**
Burro Creek						
I	0	0	n/a	0	0	0
II	319	561	57%	1.5	317	0
III	9,581	35,525	27%	5,741	3,840	0
Total	**9,900**	**36,086**	**27%**	**5,742.5**	**4,157**	**0**
McCracken Desert Tortoise						
I	9,207	27,350	34%	8,886	322	0
II	0	0	n/a	0	0	0
III	1,590	1,590	100%	1,590	0	0
Total	**10,797**	**28,940**	**37%**	**10,476**	**322**	**0**
Poachie Desert Tortoise						
I	487	29,443	2%	487	0	0
II	12	2,228	<1%	12	0	0
III	1	1	100%	1	0	0
Total	**501**	**31,672**	**2%**	**500**	**0**	**0**
Three Rivers Riparian						
I	1,057	12,743	8%	1,057	0	0
II	7,853	41,461	19%	2,073	644	5,136
III	24,714	24,714	100%	10,313	3,010	11,359
Total	**33,624**	**78,918**	**43%**	**13,443**	**3,654**	**16,495**
White-Margined Penstemon						
I	0	0	n/a	0	0	0
II	16,513	33,938	49%	14,389	2,124	0
III	289	289	100%	289	0	0
Total	**16,802**	**34,227**	**49%**	**14,678**	**2,124**	**0**
Coffeepot Mountain						
I	0	8,867	n/a	0	0	0
II	0	0	n/a	0	0	0
III	0	0	n/a	0	0	0
Total	**0**	**8,867**	**n/a**	**0**	**0**	**0**

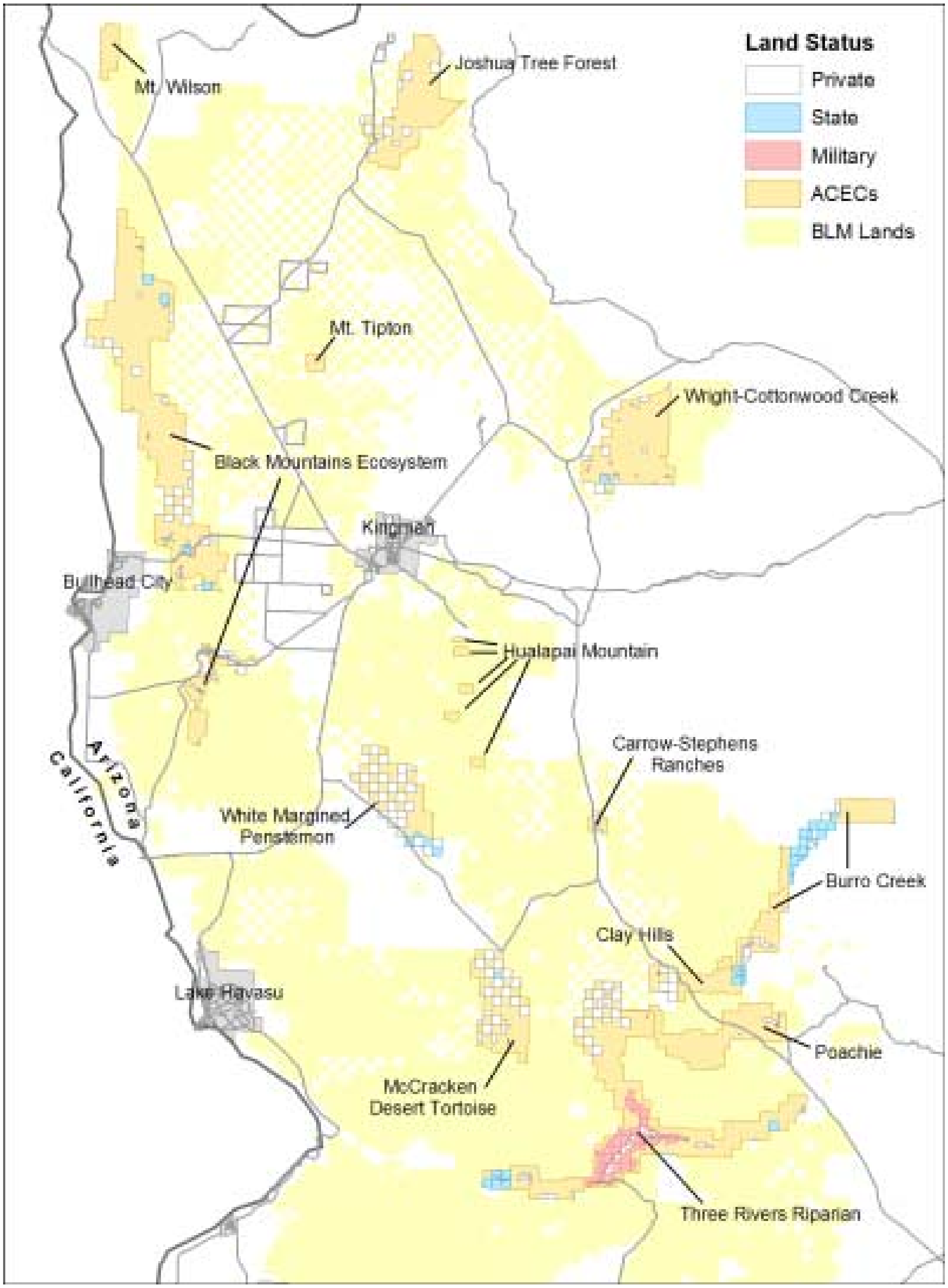

Figure 4. Private, state and federal inholdings within Areas of Critical Environmental Concern (ACECs) with significant desert tortoise habitat.

Development and urbanization of the boundary of Saguaro National Park threatens the desert tortoise populations there as well (Averill-Murray and Swan 2002). In the Tucson area, many thousands of acres of tortoise habitat have been recently lost to large residential developments in the foothills of the Santa Catalina, Tortolita, Rincon, and Tucson Mountains. Development reduces the size of populations and isolates them by creating barriers such as highways and canals (Edwards et al., 2004). Additionally, development within the Tucson foothills has displaced tortoises from their "excellent" habitat in the Rincon, Santa Rita, Santa Catalina, Tortolita and Tucson Mountains (Averill-Murray and Swan 2002, Edwards et al, 2004).

This development trend will continue as demand increases due to local population booms. Development pressure will likely continue in scenic areas in the Sonoran Desert as cramped urban lifestyles intensify the desire to flee. As one Tucson developer put it "From a market perspective, land adjoining Saguaro National Park is the closest thing in southern Arizona to ocean-front property" (quoted in Propst 1997). As Propst (1997) described:

> When the Rincon Mountain District of Saguaro National Park was established in 1933, it stood as an isolated wilderness situated 19 kilometers (12 miles) from Tucson's urban boundary. Since then, particularly in the past four decades, Tucson has experienced rapid growth averaging 2.8 percent annually, almost twice the national average. The population in Pima County has doubled since 1970, reaching over 700,000 today, and is expected to double again in the next 24 years … this growth has pushed development to the park's very boundaries and redefined it as a suburban wilderness (Propst 1997).

The Rincon Valley area contains approximately 6,000 acres that formerly provided excellent, contiguous habitat supporting dense SDT populations. In some areas densities reached 127 adults per square mile (Averill-Murray 2000, Propst 1997).

Development encroachment has therefore permeated prime desert tortoise habitat in the Sonoran Desert that had once supported great densities of tortoises. The continual development of the Sonoran Desert and degradation of Sonoran desert tortoise habitat will inevitably influence the chances of survival for the Sonoran desert tortoise. Propst (1997) continues, “Unplanned sprawl is … eroding the natural and ecological integrity of the other protected sky island mountains adjacent to the city, including Coronado National Forest, Tucson Mountain Park, and Tortolita Mountain Park.” Researchers have reported anecdotal evidence which indicates that urbanization of these areas has led to “large area-wide decreases in tortoise abundance” (Averill-Murray and Swan 2002).

Federal Development Projects

A countless number of federal development projects have been proposed, approved, and conducted within southern Arizona since the listing of the Mojave desert tortoise. Because the SDT is unlisted, no consultation with the USFWS was required for any such projects (on federal land, using federal monies, or requiring federal permitting) with the potential to impact the tortoise.

Among the development threats to SDTs is the rampant modification of washes and other ephemeral water sources for the construction and modification of agricultural diversions, roads, rights-of-way and the draining of land for development. Because SDTs can be frequently found within washes and utilize the banks of washes for constructing hibernacula, dredging or filling and other disturbance of wash sites poses a major risk of tortoise mortality and habitat loss (Barrett et al. 1990, Averill-Murray 2000). Dredge and fill operations within, or modification of, waters of the U.S., including desert washes, requires authorization by the Army Corps of Engineers in the form of a 404 permit, and the Corps issued 1,964 such permits under the Clean Water Act in Arizona from 1990-2002. Figure 5 shows the overlap of these permits with SDT habitat.

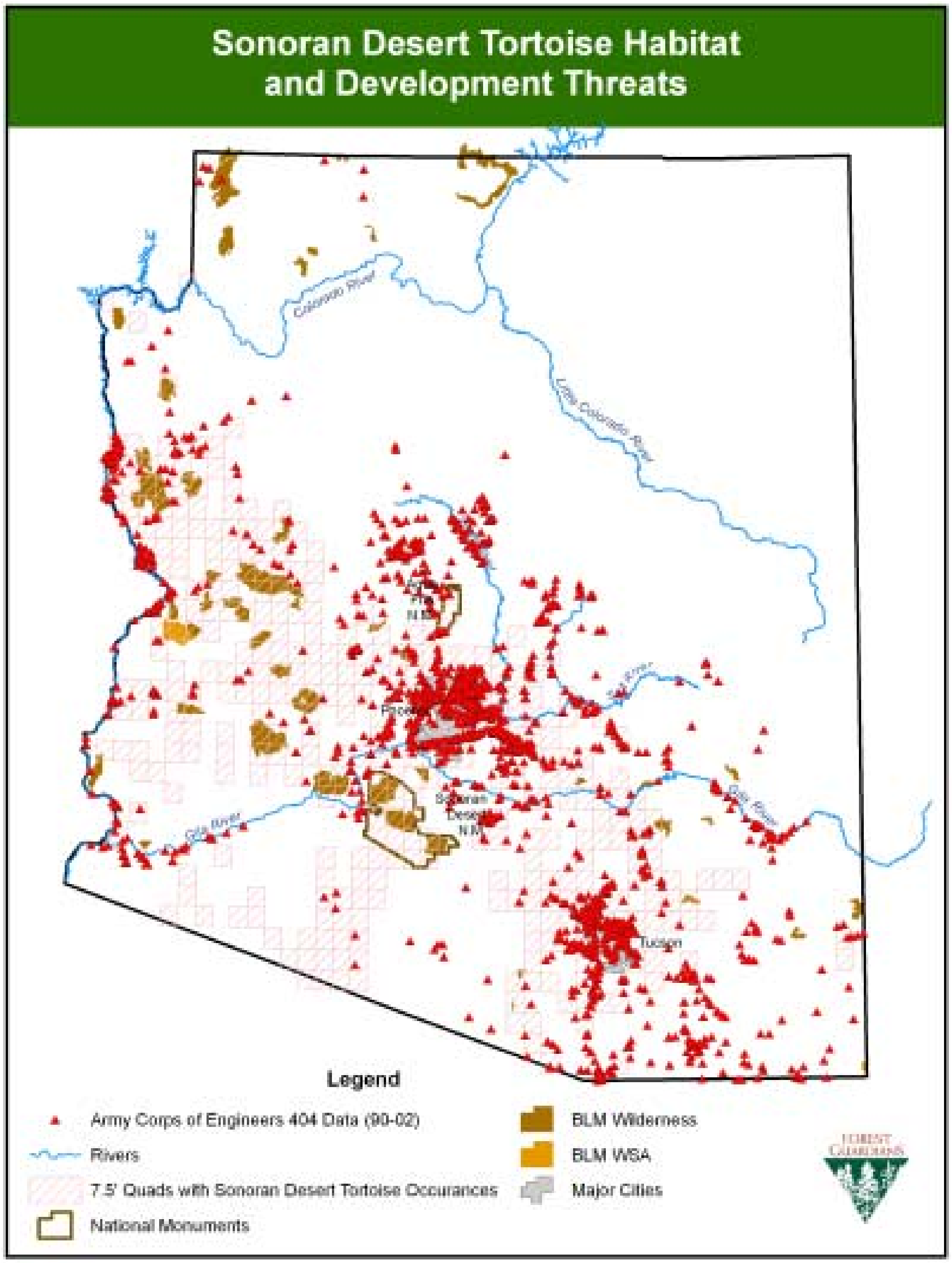

Figure 5. Distribution of 404 permits for modification of water sources related to development. 1,964 such permits have been issued by the Army Corps of Engineers from 1990-2002.

Other major federal projects have documented impacts to the Sonoran desert tortoise. Among these is the EA for the New Waddell Dam Lake Pleasant Regional Park Master Recreation Plan, being constructed in Maricopa and Yavapai Counties, Arizona by the Bureau of Reclamation (Bureau of Reclamation 1985). The EA listed desert tortoise habitat as "occurring throughout the Lake Pleasant Regional Park but is concentrated on the east side of the lake and in the central portions of the west side" (Bureau of Reclamation 1996). The EA listed the siting of a campground and additional facilities as a potential danger to tortoises (Bureau of Reclamation 1996 and 1998). The EA further stated that construction related activities will "further fragment tortoise habitat," and that "indirect effects to the desert tortoise can occur as a result of handling" (Bureau of Reclamation 1996). The EA made only brief recommendations for mitigation of specific impacts on the desert tortoise, namely the construction of fencing where needed and the conducting of public education programs. Among the recommendations for avoiding desert tortoise impacts is the "avoid[ance] of bisecting habitat," and yet the EA acknowledged this would occur with the construction of the proposed campground and facilities (Bureau of Reclamation 1996). Additional recommendations for "special status species" include only a cursory mention of "brochures on the various special status species" that will be made available to park visitors and that "monitoring and preservation of remaining populations [of special status species] should provide sufficient protection for the species" (Bureau of Reclamation 1996). Although fencing and culverts may aid in mitigating the effects of construction projects like New Waddell Dam, it is evident that the project's substantial impact on desert tortoises was not fully addressed in the EA (Brooks 1995, Boarman 1996, Bureau of Reclamation 1996).

Mining

Mining projects are one of the most widespread activities on BLM land in Arizona. Mining projects in Arizona for the period 1990-present include numerous small, privately held mining claims as well as extensive federally sponsored projects and large, corporate mines. Mining activities range from the quarrying of natural materials for landscaping, road fill and cement manufacture to the large-scale mining of coal for energy production and metals for industrial and electronic applications.

While there have been few studies investigating the effects of mining on tortoise populations, there are multiple potential impacts. Mining projects within desert tortoise habitat can affect populations through habitat fragmentation, loss and degradation, introduction of contaminants and fugitive dust (Wilshire 1980), off-road travel for exploration and access of claims, and direct mortality of individuals from mining activities, through entrapment (NPS 1999, Woodman et al. 2004), and via road mortality (Averill-Murray 2000, Boarman 2002). The San Manuel copper smelter in the San Pedro River Valley spewed filthy exhaust over tortoise habitat in the area, including San Pedro tortoise study plot (Woodman et al. 2001). Unfortunately, there are no studies of how this poor air quality affected the tortoise population although this is one of the study plots showing statistically significant declines.

We used the BLM's Land Recordation Database to examine mining claims on BLM land for the period 1990-2002. For that period alone, mining claims on BLM land totaled 9,675. Figure 6 shows overlap with SDT habitat. Of these, 6,187 were for Lode Claims, 3,261 were for Placer Claims and 206 were for Millsite Claims (Figure 6). As of 2003, 2,236 of these claims were still active and another 7,439 were closed. Based on BLM's desert tortoise habitat categorization and the data from the Arizona Heritage Data Management System's known desert tortoise occurrences by 7.5’ quadrangle, mining claims overlapping with desert tortoise habitat numbered 4,670, or 48% of all the mining claims on Arizona BLM land for the period 1990-2002. Within tortoise habitat, 1,096 of these claims were active and the other 3,574 were closed as of 2003.

Documented impacts to desert tortoises from mining activities within Organ Pipe Cactus National Monument over the same period are telling. During 1999-2000, reclamations of more than 400 abandoned mining lands features revealed evidence of juvenile tortoise mortality associated with mine sites. The features ranged from shallow bulldozer scrapes to mineshafts in excess of 300 meters deep. Monument staff documented tortoise carcasses within two mineshafts (NPS 1999). This documentation serves to confirm that there likely are impacts of the over 4,600 active and abandoned mine claims processed by the BLM since 1990. The thousands of claims filed over this period may have contributed to the recent decline in desert tortoise numbers.

In addition to mining claims on BLM land, several large private and federal mining operations have taken place within tortoise habitat since 1990. One of these is the Whitecliff mine, also on BLM land, near Safford, Arizona. The BLM prepared an EA for the Whitecliff Mining Plan in late 1989. The official EA document listed the desert tortoise among the major issues to be resolved. The mining plan describes the principal activity to be centered around “natural drainage channels” and indicates that the “area to be mined consists of steep vertical cliffs, mining will essentially consist of moving the cliffs back from the drainage channels” (BLM 1989). Project surveys in 1989 located three desert tortoises within 200 yards of the mine site, and five desert tortoises had been found within one mile of the mine site the previous year (BLM 1989).

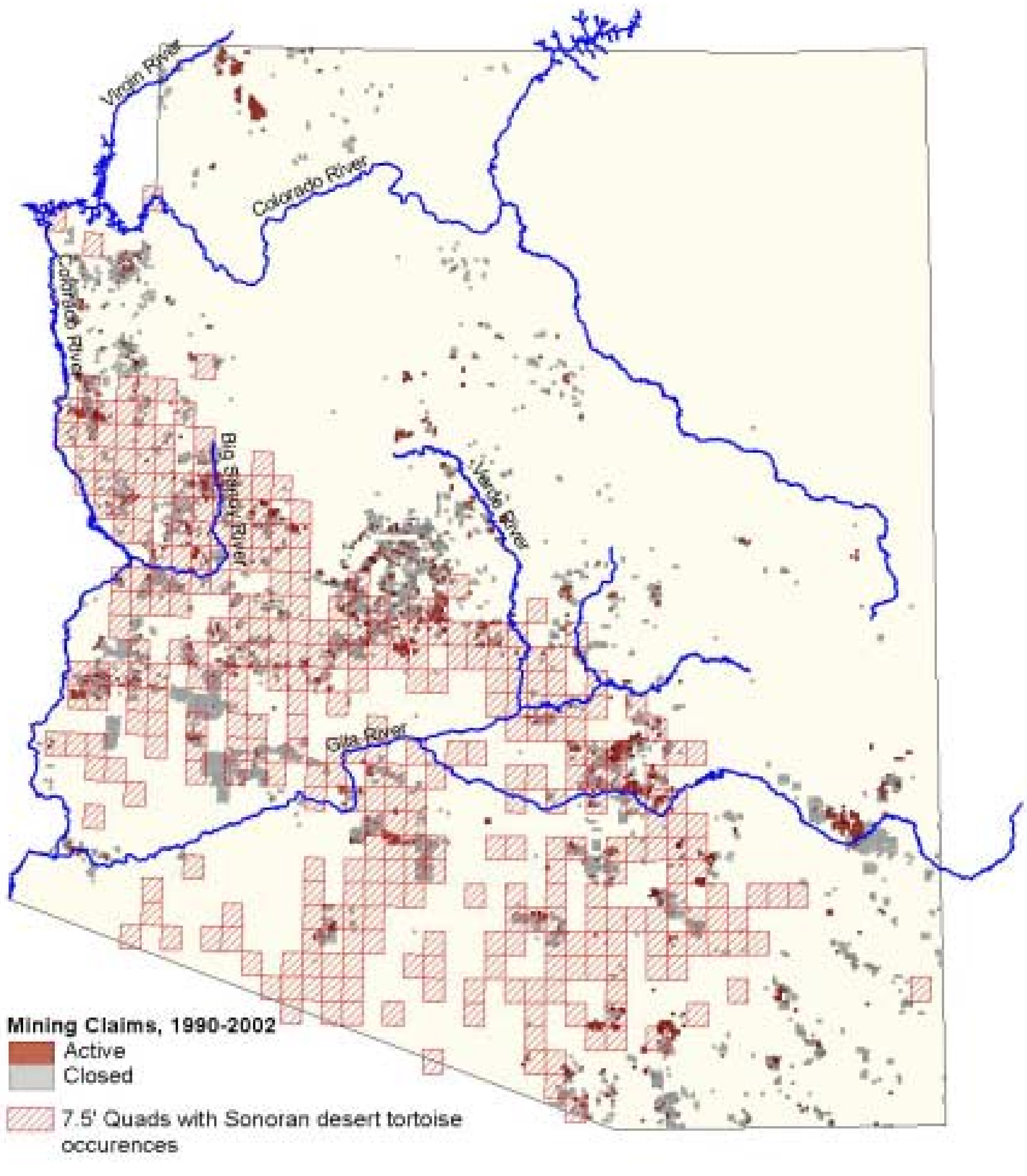

Figure 6. Mining claims on BLM land and known occurrences of desert tortoises in Arizona. The map illustrates active and closed mining claims recorded in the BLM's LR2000 database for the period 1990-2002. The claims number 9,675.

International Border Patrol Activities

The international border between the USA and Mexico crosses through over 200 km of the range of the SDT. The border between the states of Arizona (USA) and Sonora (Mexico) is actively monitored by the U.S. Border Patrol to manage unauthorized border crossings. Border patrol activities have been intensified in recent years, as has the construction of associated infrastructure projects.

These activities at the international border may result in direct and indirect take of Sonoran desert tortoises in a number of ways. Construction of facilities and all weather high-speed dirt roads can result in direct take of tortoises and loss of habitat. Border control camps with open food and water caches and associated trash may attract and support increased numbers of predatory ravens. The border wall (12-15 feet high) may provide perch sites for ravens with vantage points that would be otherwise unavailable. The border infrastructure itself needs to be carefully sited to avoid directing passage of unauthorized border crossings into areas of sensitive habitat, though unfortunately, much of the infrastructure construction has been exempted from compliance with federal and state environmental laws through use of waivers.

The fence, deep trenching, and associated infrastructure will further fragment the SDT and prevent gene-flow across the Arizona-Sonora border. Recovery of declining populations of SDT may rely heavily on the immigration of new individuals from adjacent mountain ranges (Edwards et al., 2004). Border activities need to be compatible with the evolutionary history of gene flow among disjunct SDT populations to help ensure their long-term persistence.

(2) OVERUTILIZATION FOR COMMERCIAL, RECREATIONAL, SCIENTIFIC, OR EDUCATIONAL PURPOSES

Poaching and Collection as Pets

Although hard data on the number of tortoises collected from the wild does not exist, it has been reported anecdotally in many instances (Stewart 1991, USFWS 1994b, Averill-Murray 2000). Tortoises are illegally collected for pets, food and commercial trade, and tortoises from permanent plots have been found in cities and towns dozens of miles away (USFWS 1994b). A Mojave population that was radio-monitored during the period 1987-1991 had possible poaching incidence rates as high as 43.7% (Stewart 1991). Los Angeles residents have reportedly collected tortoises for food or cultural rituals in recent years (USFWS 1994b, Berry et al. 1996).

Fritts and Jennings (1994) reported that tortoise numbers in the vicinity of Ures/Santiago and Ortiz/La Misa in Sonora, Mexico had been reduced by exploitation for food. A recent report indicates that educational outreach is needed to address collection of desert tortoises for pets and commercial uses in Sonora (Torres and Andrade, 2005).

Reintroduction of non-local wild tortoises is likely as much a problem as collection for pets, because of their potential to behave as disease vectors, as well as their likely disruption of wild populations' social systems (Barrett et al. 1990, Grove and DeFalco 1995, Averill-Murray 2000, Howland and Rorabaugh 2002). Instances of African spurred tortoises (*Geochelone sulcata*) were found outside of Tucson in 1999-2000 (Averill-Murray 2000). These exotic tortoises were found to have fecal samples consisting solely of wild plant material, indicating that they had been living in the wild for an extended period of time (Averill-Murray 2000).

Shooting, Vandalism and Trash

Shooting and vandalism pose threats to individual Sonoran desert tortoises. Several shootings are mentioned in Howland and Rorabaugh (2002). Woodman et al. (2001) found the carcass of an unmarked tortoise that had been killed by gunshots on the Four Peaks study plot.

Trash, particularly balloons and remnants, may pose threats to individual Sonoran desert tortoises. Balloons may travel hundreds of kilometers into remote desert areas (Walde et al 2007). Walde et al 2007 described finding a Mojave desert tortoise that had ingested a balloon and attached ribbon; Burge (1989) reported on a tortoise that lost a limb from entanglement in a balloon string. The presence of balloons has been noted on SDT study plots including Harcuvar Mountains and San Pedro Wash (Appendix 1).

(3) DISEASE OR PREDATION

Upper Respiratory Tract Disease, Cutaneous Dyskeratosis and other Pathogens

Populations of the desert tortoise in the Mojave Desert of southern California have been devastated by outbreaks of Upper Respiratory Tract Disease (URTD) and this was a factor in the federal listing of that population (USFWS 1994b). The disease is highly contagious and is spread through mucous exudates or direct contact with infected animals (Brown et al. 1999a and 1999b). Disease symptoms include nasal discharge, blepharitis, conjunctivitis, excessive tearing, edema of the eyelids and ocular glands, mouth bleeding, wheezing, anorexia and weight loss (Brown et al. 1999b, Berry and Christopher 2001). URTD has been documented in SDT populations in Arizona (Barrett 1990a, Barrett 1990b; Riedle and Averill-Murray 2003). Monitoring the disease status of desert tortoises throughout their range is considered important for understanding the dynamics of URTD in wild populations (USFWS 1994b).

At least 2 species of mycoplasma are known to cause URTD, *Mycoplasma agassizii* and *M. testudineum* (Brown et al 2004). Because symptoms of URTD may be confused with those caused by other diseases and because infected animals may be asymptomatic, it is necessary to perform antibody tests to determine previous or present exposure. An enzyme-linked immunosorbent assay (ELISA), which tests for antibodies (indicating previous or present exposure) for the mycoplasma that cause URTD, has been developed and used to detect URTD in desert tortoises (Wendland et al 2007).

Appendix 2 summarizes disease reports in various Sonoran desert tortoise populations. During 2001-2002, tortoises were tested at various study sites in Arizona. While no *M. agassizii* antibodies were detected in tortoises at three remote sites (Sugarloaf, Florence, and Silverbell Mountains), 23 out of 43 tortoises in two sites adjacent to Tucson (Saguaro National Park East

(SNPE) and Ragged Top Mountain) tested positive for *M. agassizii* antibodies (Riedle and Averill-Murray 2003). None of the SNPE tortoises were exhibiting clinical signs of URTD at the time sampling occurred, but five tortoises at SNPE have exhibited clinical signs of URTD since 1999. These signs have included wheezing, wet and bubbling nasal discharge, and runny eyes. Observational records since 1999 indicate that these symptoms have sporadically recurred in all tortoises that have exhibited them (T. Esque and C. Schwalbe, U.S. Geological Survey, and D. Swann, National Park Service, unpublished data cited in Jones et al., 2005).

Since 2001, the ELISA test has been applied to blood drawn from at least 184 Sonoran desert tortoises on the BLM/AGFD study plots. Two tortoises from the Hualapai Foothills and Tortilla Mountains study plots were positive for antibodies to *Mycoplasma agassizii* (Woodman et al. 2006, 2007) and suspected in two additional tortoises, one from a third area (Harcuvar Mountains plot). Furthermore, seropositive results were obtained from 21 tortoises in and near Saguaro National Park and 2 from Ironwood Forest National Monument (Jay and Averill-Murray 2002). Dickinson et al. (2005) reported two animals were seropositive and three were suspect (marginal serology values). These animals were in the Harcuvar, Little Shipp, or Sand Tank Mountains (the paper did not report precise location). Jones et al. 2005 provide the most recent survey of Mycoplasma infection in the Tucson area in an analysis of samples from 138 free-ranging tortoises. Of the 122 adult free-ranging desert tortoises sampled, 69 (56.6%) were seropositive, 42 (34.4%) were seronegative, and 11 (9.0%) were suspect. All 16 (100%) juvenile free-ranging desert tortoises were seronegative.

Most of the SDT health evaluations have focused on testing for *Mycoplasma agassizii*. However, an additional bacteria *M. testudineum* has also been isolated from desert tortoises and shown to induce URTD when inoculated into healthy tortoises (Brown et al., 2004). A wild

Mexican desert tortoise that tested negative for antibodies to *M. agassizii* had a suspect positive test for antibodies to *M. testudineum* (Brown et al 2006). Further studies are needed to determine the extent of *M. testudineum* infection in SDTs, its clinical effects, and the consequences of simultaneous infection with both *M. agassizii* and *M. testudineum* to the health and mortality rates of SDT populations.

It has been hypothesized that Sonoran may be less susceptible than Mojave desert tortoises in part because they do not form such high density populations (and thus are less likely to contact infected tortoises) and the biseasonal rainfall regime offers them more opportunity to rehydrate (Dickinson et al. 2002). If this is true, it invites useful management direction for the need to reduce environmental stressors particularly during drought periods. However, the threat that URTD poses to these populations should not be underestimated because of URTD's major impact to the Mojave desert tortoise population (USFWS 1994b).

The *Mycoplasma* that cause URTD are known to infect a number of different tortoise species (Jacobsen et al. 1991, Brown et al. 1999a, 1999b, 2001 and 2004). It has also been hypothesized that URTD outbreaks within the Mojave Desert may have been caused, or at least spread, by the release of Mycoplasma infected captive desert tortoises or other exotic tortoise species kept as pets (USFWS 1994). On several occasions, African spurred tortoises (*Geochelone sulcata*), a species known to harbor a number of pathogens for desert tortoises, have been documented outside of Tucson (Averill-Murray 2000, Jones et al. 2005).

Jones et al found that 64 blood samples (48.4%) collected from adult captive desert tortoises in the Tucson area tested ELISA positive. This level was lower than free-ranging tortoises in the area (Jones et al. 2005). They concluded that captive tortoises are not currently an important reservoir of *M. agassizii* for the wild population around Tucson because a very high percentage of free-ranging suburban tortoises have already been infected. They proposed that the high percentage of seropositivity in suburban tortoises may be related to anthropogenic or environmental stress caused by urbanization. If this is the case, the stress of habitat degradation and other threats may contribute to disease outbreaks and disease-caused die-offs.

Mycoplasma specific antibodies are transferred from infected female tortoises to hatchlings without transmission of the disease agent (Schumacher et al. 1999). Although antibody levels were lower in yolk and hatchling plasma than in adult female plasma, the presence of antibodies was still detectable up to one year after hatching (Schumacher et al. 1999). The study's findings suggest that, "these passively acquired antibodies may play a role in the pathogenesis of mycoplasma-induced respiratory tract disease and other diseases" (Schumacher et al. 1999).

Cutaneous Dyskeratosis (CD) has been observed within virtually all of the populations of tortoises in the Sonoran Desert (Woodman et al. 2004, 2005, 2006, 2007). The disease is characterized by scarring and lesions on the shell, most typically appearing on the plastron or carapace, but also found on the scales of the forelimbs (Averill-Murray 2000, Berry and Christopher 2001, Homer et al. 2001). Affected areas are often grey-white in color and have a flaky appearance, with the initial symptoms originating at the seams between the scutes (Jacobson et al. 1994, Homer et al. 2001). Although no serious detrimental effects of the disease have been observed directly higher mortality rates have been noted for some populations of desert tortoises affected by CD (Homer et al. 2001). The consensus among the November 2002 Tortoise Health and Disease Workshop participants was that (a) the location and histologic appearance of lesions seen in tortoises with cutaneous dyskeratosis are suggestive of either a deficiency disease or toxicosis or both, and (b) that the flaking and loss of scute laminae and thinning of bone observed in tortoises with cutaneous dyskeratosis may render the tortoise more vulnerable to other diseases such as fungal infections and multicentric visceral inflammation. Such a disease may inhibit or slow growth rates, and the thin shell may make the tortoise more vulnerable to predators (Berry and Jones, 2004).

Additional pathogens have been noted in free-ranging tortoises in both the Mojave and Sonoran Deserts. Among these are *Pasteurella* sp., *Streptococcus* sp., *Staphylococcus* sp., herpesvirus, *Pseudomonas* sp. and *Salmonella* sp. (Pettan-Brewer 1996, Dickinson et al. 2001, Riedle and Averill-Murray, 2003). Although the impacts of these additional pathogens on tortoise populations are unclear, their presence may again be correlated with high levels of physiological stress indicative of habitat deterioration and other threats.

Boarman and Kristan (2008) found that the incidence of both disease types helped to explain population sizes on 17 study plots. Possible clinical signs of URTD and CD were found at a majority of the plots (65% and 88%, respectively) and antibodies for *Mycoplasma agassizii* were found in two to four tortoises at two to three plots (also see Appendix 2). There was a nearly significant ($p=0.066$) effect of incidence of CD on population trends, offering weak support to the hypothesis that CD causes population declines.

Predation

As Averill-Murray et al. have noted "[p]redation affects all tortoise populations to varying degrees." Native predators of adult, juvenile, and hatchling tortoises and tortoise eggs include mountain lion (*Felis concolor*) (which are the only predators known to be able to break an adult tortoise's shell), coyote (*Canis latrans*), common raven (*Corvus corax*), kit fox (*Vulpes macrotis*), bobcat (*Lynx rufus*), gray fox (*Urocyon cinereoargenteus*), badger (*Taxidea taxus*), Gila monster (*Heloderma suspectum*), golden eagle (*Aquila chrysaetos*) and other raptors, greater roadrunner (*Geococcyx californianus*), coachwhip (*Masticophis flagellum*), gopher snake (*Pituophis melanoleucus*), and kingsnake (*Lampropeltis getula*) (Averill-Murray et al. 2002b). The summary of threats identified on permanent study plots included in Appendix 1 includes observations of natural predation by mountain lion on tortoises on 5 of the 17 study sites. Non-native predators include free-ranging dogs (Averill-Murray et al. 2002b).

While loss of individuals to predation has always impacted desert tortoises to some degree, in the past, predator/prey relationships were balanced. However, today, populations of certain predators are "subsidized" by anthropogenic sources of food and water, and have expanded to such high levels that they may have significant negative effects on Sonoran desert tortoise populations (Boarman 2002a). The most important of these human-subsidized predators are common ravens and coyotes.[3]

Ravens prey on juvenile tortoises, whose shells may not fully harden until seven years of age, by pecking into their shells (Boarman 2002b). Depredation of hatchlings by ravens is considered to be a significant factor holding back recovery of the Mojave desert tortoise population (USFWS 1994). Studies in the Mojave Desert have shown that ravens nesting closer to human settlements have higher survival and reproductive success (Kristan et al. 2004, Webb et al. 2004). Ravens have been shown to be more numerous in areas with a greater human influence (Knight and Kawashima 1993, Knight et al. 1993, Boarman et al. 2006), predation risk from ravens is higher near active raven nests and human-provided resource sites (Kristan and Boarman 2003), and tortoise population declines have been linked with raven population increases (Boarman 2002a).

[3] We are not advocating lethal control of ravens or native canids, rather we are noting the threat to SDTs when human activities result of destabilized prey/predator relationships. The long-term solution is usually curtailing human land use in order to restore or protect interior habitats and reduce edge effects.

When adult turtle populations are declining, juvenile mortality must be reduced to ensure recruitment of new individuals into the breeding population (Congdon et al. 1993). This finding is based on well-developed life history theory. Therefore, in tortoise populations that are experiencing overall declines, additional losses of juveniles to ravens may decrease the stability or prevent recovery (Boarman, 2002). Raven populations in the Sonoran Desert have increased 14-fold in recent decades (Boarman and Kristan 2006), and this increase is closely linked with the increased and growing human presence in the desert.[4] The increases are likely facilitated by increased availability of food and water resources at landfills, rural and urban developments, along heavily traveled roads, and at agricultural areas, particularly dairies. Although overall abundance is currently lower, the increase in raven populations has been greater in the Sonoran Desert than the Mojave, and thus impacts to SDTs may be increasing more rapidly. In 2002, Woodman et al. observed ravens daily on the Bonanza study. Habitat fragmentation leads to increases in the number of ravens in a given area (Boarman and Berry 1995). The drastic increase in raven populations is likely to continue without careful management.

Increased human presence has also subsidized populations of canids. Coyotes thrive around human settlements, and have greatly increased their range. Feral and free-roaming dogs are also a result of increased human presence, and are believed to cause significant mortality to Mojave desert tortoises (Boarman 2002a, Bjurlin and Bissonette 2004). The data summarized in Appendix 1 identifies domestic or feral dogs as problems on 4 of the 17 permanent study sites. Feral and free-roaming dogs are suspected of causing tortoise mortalities at the Hualapai Foothills, Eastern Bajada, San Pedro Wash, and Bonanza Wash monitoring plots (AIDTT 2000, Averill-Murray et al. 2002b, Woodman et al. 2003, 2005, 2006, 2007).

[4] Pima County's population has grown by 67,204 in just 3 years. Visit on-line at www.pagnet.org/population/primer.htm

(4) INADEQUACY OF EXISTING REGULATORY MECHANISMS

Existing regulatory mechanisms have been insufficient to protect and recover Sonoran desert tortoise habitat and populations. Current management is both voluntary and spotty, and suffers from a lack of interest and funding (AIDTT 2003, Ted Cordery, pers. comm.). The primary agencies currently involved in the conservation of the desert tortoise in Arizona are the Arizona Game and Fish Department (AGFD), BLM, USFS, and NPS. Additionally, agencies and entities with some involvement in monitoring and mitigating impacts to desert tortoises include the Arizona State Land Department (ASLD), the Bureau of Reclamation (BOR), the Bureau of Indian Affairs (BIA), Pima County, the Yuma Proving Grounds, the Barry M. Goldwater Range, and the Florence Military Reservation.

Legislation of primary importance which currently or historically has affected the conservation status of the SDT includes the ESA, NEPA, and the Wilderness Act. While much of the information presented here is summarized in Averill-Murray (2000), there have been some updates to land use, resource management and habitat conservation plans, and these are discussed here.

Current Legal Status

The Sonoran desert tortoise in Arizona currently does not enjoy any legally mandated protection, except against collection, although it is considered a "species of special concern" in Arizona, and the AGFD has considered the tortoise a candidate species for threatened status since 1988 (Howland and Rorabaugh 2002). It is illegal to kill or capture tortoises from the wild (with the exception of special permits), and possession for trade, sale or other commercial purposes is illegal (Howland and Rorabaugh 2002). The SDT is also on the BLM and USFS lists of sensitive species (Averill-Murray 2000). Internationally, the tortoise is considered a threatened species in Mexico, and the 1986 Convention on International Trade in Endangered Species of Wild Fauna and Flora requires a permit for the export of tortoises to member countries (Fritts and Jennings 1994, Grover and DeFalco 1995, Bury et al. 2002, Howland and Rorabaugh 2002).

After the USFWS's 1991 ruling that listing of the SDT population was not warranted, the species became a Category C2 candidate species, for which adequate information was lacking to make a listing determination. Category C2 classification was discontinued by the Service in 1996, and the SDT currently has no status under the ESA (61 FR 7596**,** Howland and Rorabaugh 2002).

Agency Conservation

Arizona Interagency Desert Tortoise Team (AIDTT)

The AIDTT was formed in 1985 to coordinate interagency research and management of desert tortoise populations in Arizona. Member agencies include the AGFD, ASLD, USFS, BLM, BOR, BIA, USFWS, NPS, US Geological Survey and several Department of Defense military reservations (AIDTT 1994 and 1996). The AIDTT Memorandum of Understanding, signed in 1994, established specific objectives for the team; 1) ensuring the survival of the species, 2) preventing loss of the species; and 3) improving the quality of habitat in Arizona, with the team to function as an advocate for the tortoise (AIDTT 1994 and 1996).

The team drafted a management plan for the desert tortoise in Arizona in 1996, with recommendations regarding monitoring and research of population dynamics, habitat quality and disease (AIDTT 1996). The management plan recognized that past monitoring efforts for the SDT had been woefully inadequate, and that the available data was so incomplete as to not be able to detect anything less than catastrophic population declines. The plan thus called for more comprehensive and regular monitoring, in order to be better able to determine population trends. However, the plan outlines no concrete objectives and no means for obtaining money to achieve its goals (AIDTT 1996).

The plan recognizes the need for more research on SDTs, especially the need for long-term studies because of the tortoises' long lifespan, but again, no concrete plans or objectives are stated. The plan imposes no mandatory, binding management prescriptions on AIDTT members, instead providing a range of voluntary "management options" that may be employed by participating agencies to better manage SDT populations, and it explicitly states that these options are "not intended to be a mandatory management program that participating agencies must implement" (AIDTT 1996). The "management options" include continuing the ban on the collection of desert tortoises. The plan recommends the establishment of educational programs to educate the public about desert tortoises and threats to their survival. It cautions against allowing the release or relocation of captive desert tortoises, because of the possibility of introducing disease into wild populations. It recommends against the use of predator control programs to benefit the tortoise, as they have not been shown to be effective, and that predator control programs for species other than desert tortoises be evaluated to determine their effects on tortoise populations.

Among the management plan's recommendations are the establishment of Sonoran Desert Management Areas (SDMAs) on federal lands, similar to those that have been proposed for the Mojave desert tortoise (DTRT 1993). The team recommends that desert tortoise SDMAs be established only within Category I and II habitats, with the eventual size, distribution and management criteria to be determined through further research (AIDTT 1996). Within SDMAs, the team recommends that grazing by cattle and sheep either be eliminated, deferred from the desert tortoise emergence period (spring green-up) to October (the peak of SDT activity), or allowed only if sufficient soil moisture is present to ensure adequate forage for both livestock and wildlife like the tortoise, with monitoring conducted to make sure this is so. In addition, it suggests that SDMAs either be withdrawn from future mineral entry or subject to surface occupancy restriction during peak tortoise activity times, and that sales of minerals, especially boulders, be evaluated to determine the effects on SDT populations.

While the creation of SDMAs, with the attendant restrictions outlined in the management plan, would be a vital step in beginning to stabilize and recover SDT populations, these management areas have not been created, and thus grazing and extractive uses of the land have continued without consideration of the SDT. It seems clear that without the mandatory protections afforded under the ESA, the impetus to stabilize and recover SDT populations does not exist in Arizona.

This lack of political willpower, and the subsequent failure of the current management plan to prevent loss of habitat and population declines, is well known to the AIDTT. In a March 2003 presentation, the team recognized that the 1996 plan was insufficient to benefit the Sonoran desert tortoise, citing spotty and inadequate implementation of the management plan, reduced participation by members in AIDTT activities, and a decrease in funding for monitoring and research (AIDTT 2003). Because of this failure, and the threat of ESA listing, the presentation called for a strong state conservation strategy and agreement with tangible goals, objectives and commitments that would be fully funded. However, even when such an agreement may be completed, it will not go into effect on lands administered by the BLM until the BLM can incorporate it into RMPs, either through the planning process or through plan amendments (Ted Cordery, pers. comm.).

Arizona Game and Fish Department (AGFD)

The AGFD is the agency with primary responsibility for wildlife management in Arizona, including species management on private, state and federal lands, with the exception of national parks and monuments and Indian reservations (Howland and Rorabaugh 2002). The AGFD currently lists the desert tortoise on their list of Wildlife of Special Concern in Arizona. This designation recognizes that "significant habitat losses and threats" imperil the SDT (AGFD in prep.) and that the need exists to act "forcefully" to protect its habitat. However, while this designation indicates the need for special management consideration, it does not confer any additional legal protection to the tortoise or its habitat (AGFD in prep., Averill-Murray 2002). The AGFD enacted a regulation on January 1, 1988 prohibiting the take of desert tortoises from the wild, with the exception of special circumstances. Prior to that time, the Arizona Game and Fish Commission allowed the possession of one lawfully captured tortoise per person (Averill-Murray 2000). This prohibition on take is currently the only binding protection measure for SDTs. However, the 2000 status report on the Sonoran desert tortoise (Averill- Murray 2000) indicates that, while taking of desert tortoises is prohibited, enforcement of the law is "difficult at best." In addition to being largely unenforceable, the general public is mostly unaware of the law, with the report citing the need for "substantial education efforts" to make them aware (Averill-Murray 2000).

The AGFD also administers the standards for mitigation measures to be applied for project mitigations by the AIDTT signatories (AGFD 1997 and 2000). The AGFD is the principal agency, either through staff or contractors, that conducts long-term monitoring studies of desert tortoise populations in Arizona, and agency biologists have been responsible for the publication of a significant body of scientific literature on SDTs (AGFD 1990, 1996 and 2000, AIDTT 1996, 1997 and 2000, Averill-Murray 2000, Averill-Murray et al. 2002a and 2002b, Averill-Murray and Klug 2000, Averill-Murray and Swan 2002, Woodman et al. 1991-2003).

Bureau of Land Management (BLM)

As already described, the BLM is the single largest land manager of desert tortoise habitat in Arizona, responsible for almost 4.7 million acres of desert tortoise habitat across the species' range in Arizona (Table 1 and Figure 2). Of these lands, over 2.5 million acres are considered as Category I and II lands, within which the agency has an obligation to "maintain stable populations" (BLM 1989).

The BLM has produced several documents regarding the status and management of desert tortoises on public lands. A 1987 agency report addressed the status of the species and made recommendations for improving the management of desert tortoise habitat on BLM land (BLM 1987). This report was followed by the preparation of a range-wide management plan for the tortoise and an Arizona-specific management document (BLM 1988 and 1990). The range-wide plan established the habitat categorization scheme described earlier. The plan further identified the need to address management concerns, including livestock use, mining, inholdings and OHV use that were affecting, and continue to affect, the status of the desert tortoise (BLM 1989). Also included in the plan, under a no net-loss policy for desert tortoise habitat relative to land-use decisions, was a provision to compensate for residual impacts to tortoises after mitigation measures were incorporated into proposed actions (BLM 1989).

In 1991, the BLM established a compensation policy for the desert tortoise (BLM 1992). In 1999, the BLM modified its compensation policy, and compensation is now determined through varying rates based on the category of tortoise habitat to be affected (Averill-Murray 2000). The new policy concentrates on the careful disposition of funds and has been reported to have resulted in favorable management actions for the tortoise, including project relocations, construction of fencing and culverts for crossing, and land acquisition (Averill-Murray 2000).

There are seven Field Offices (FO) in Arizona that contain SDTs: Yuma, Safford, Flagstaff, Phoenix, Lake Havasu, Kingman, and Tuscon. Each of these FOs had integrated either the 1991 rangewide desert tortoise management plan or the 1996 Arizona desert tortoise plan into their RMPs through plan amendment, although each FO did so to varying degrees (Ted Cordery, pers. comm.). As the technical advisory team for the BLM, the AIDTT provides "advice and technical expertise to the BLM" regarding desert tortoise issues on public land (Averill-Murray 2000). In addition, several National Monuments containing SDT habitat have been designated by presidential proclamation including Ironwood Forest and Sonoran Desert National Monuments.

The boundaries of the Phoenix FO have been altered twice in recent years, with the result being that a patchwork of RMP's guide actions within that office. They are currently in the planning process to create a new RMP that covers the whole FO, and this RMP will fully integrate the 1996 Arizona Desert Tortoise management plan into the RMP. A separate RMP is being developed for the Sonoran Desert National Monument.

The Kingman FO has completed a proposed RMP that fully integrates the prescriptions of the 1991 Rangewide plan for desert tortoises. Currently, the Kingman FO has experienced large road construction projects that require compensation to be paid, as they impact desert tortoise habitat. Compensation goes into a statewide "Tortoise Fund," which is used to buy biologically critical desert tortoise habitat, especially in areas in which BLM administered land is interspersed with private or state land. The Kingman FO also requires that those who work on construction projects in desert tortoise habitat take classes educating them on desert tortoise biology and relocation procedures (Becky Peck, pers. comm.).

The Lake Havasu FO finalized its new RMP in 2007. The RMP adopted the BLM's 1991 desert tortoise management recommendations.

Ironwood Forest National Monument, within the borders of the Tuscon FO is also in the process of creating its own management plan. However, this new RMP appears unlikely to address livestock grazing impacts to tortoise habitat since the BLM is currently renewing 10-year grazing permits for all of the Monument's allotments.

Although the various field offices have been incorporating desert tortoise management guidelines into their RMPs, the document they have been incorporating is the 1996 AIDTT plan, which the AIDTT itself now recognizes is lacking in participation, funding and enforcement. This plan contains many recommendations, but asks for no firm commitments of time or resources. In addition, the 1996 AIDTT plan recognized that the habitat categorizations it outlined were incomplete, and that final categorizations would need to be changed to reflect actual conditions. However, the FOs have adopted these imperfect categorizations wholesale, without any site-specific adjustment, leading to a reduction in their benefit.

The 1997 Arizona Standards and Guidelines for Rangeland Health set standards for upland, riparian and desired plant community health (BLM 1997). The document provides guidelines for maintaining percentages and composition of plant cover, reducing erosion, and maintaining favorable riparian conditions and water quality. However, based on the assessment of the BLM's compliance with NEPA review for grazing allotments presented earlier, the 1997 document may not be having a significant beneficial effect on the ground within tortoise habitat.

Additionally, special management areas, including ACECs, Wilderness Study Areas and Wilderness, exist within desert tortoise habitat in Arizona. Among these, Wilderness designations and ACECs are by far the most important for protecting desert tortoises on BLM land. ACECs contain over 300,000 acres of BLM categorized desert tortoise habitat. Although ACECs are ostensibly regulated with the applicable RMPs to avoid impacts to sensitive resources, in practice RMP language is often vague and the agency typically makes exceptions to RMP stipulations for land use (Oliva 2004). As discussed earlier, a significant portion of ACECs are at risk from development of private inholdings, as well as other potentially negative land use impacts, including livestock grazing and OHV use (Table 6).

Significantly, wilderness designations contain some 500,000 acres of BLM categorized habitat. Although still subjected to livestock grazing, these areas are excluded from mining and OHV activities and, in addition to National Parks and Monuments, probably represent the most significant acreage of protected habitat in the state.

U.S. Fish and Wildlife Service (USFWS)

In conjunction with its consulting duties under the ESA, discussed earlier, the Service's Region I office is the lead entity for its management activities related to the Mojave desert tortoise populations, for which the USFWS is supposed to protect populations from jeopardy, prevent adverse modification of their critical habitat, and implement their recovery plan. Additionally, the Service operates a number of wildlife refuges in Arizona that contain populations of SDTs. These include the Kofa, Cabeza Prieta, Buenos Aires, Havasu, and Imperial National Wildlife Refuges (NWRs). Among these, the larger Kofa and Buenos Aires refuges contain habitat that is contiguous with habitat on the Yuma Proving Ground (Kofa) and Barry M. Goldwater Range and Organ Pipe Cactus National Monument (Cabeza Prieta). As such, these NWRs are especially valuable in maintaining relatively protected habitat for Sonoran desert tortoise populations that are otherwise exposed to the threats described earlier (Burge 1980).

Tortoises within the NWRs enjoy protection from livestock grazing and OHV use. Additionally, the Arizona Desert Wilderness Act of 1990 adds another layer of protection for 355,000 acres of tortoise habitat within the Havasu, Kofa and Cabeza Preita NWRs (Averill-Murray 2000).

National Park Service (NPS)

National Park Service (NPS) administered Parks and Monuments serve as important refuges for SDT, and in theory provide a relatively high level of protection from threats. NPS currently has no special conservation policy with regards to the SDT, although a multi-park management plan for the tortoise was proposed in 1994 (NPS 1994). The Park Service's Organic Act of 1916 mandates that the agency:

> conserve the wildlife therein and provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations. 16 U.S.C. § 1.

All wildlife within NPS administered areas is protected and cases of wildlife possession or removal are both enforced and prosecuted (Averill-Murray 2000). The principal areas administered by the NPS and containing tortoise habitat are the Organ Pipe Cactus National Monument and Saguaro National Park. Together, these areas protect over 400,000 acres of land, 25% of which is estimated by be suitable desert tortoise habitat (Robichaux and Wirt 1995-1996 and 1998, Wirt et al. 1998a and 1998b, Wirt et al. 1999, Averill-Murray 2000). Additional scattered habitat and tortoises occur within the popular Lake Mead National Recreation Area.

Most of Organ Pipe Cactus National Monument (OPCNM) is managed as a designated wilderness and is protected from many anthropogenic impacts. Livestock grazing is nor allowed on OPCNM. However, the monument has a high incidence of documented illegal activities that likely affect tortoises. Incident reports for illegal off-roading activity within the monument numbered 119 for the period 2/24/1996 to 4/13/2002, along with 860 speeding violations for the period 1/5/96 to 6/14/2002, and 30 violations for destruction and damage to natural resources for the period 2/2/1999 to 4/4/2002. Additional records indicate that 40 violations were issued for the destruction of plants during the period 3/5/1996-11/8/2001, and that six incidents of arson occurred during the period 5/3/98-4/14/2002 along with 18 fire violations not considered arson. One incident of harassment, injury or take of a federally endangered animal (unspecified) was also reported in 2000. There are also high levels of cross-border drug smuggling, immigration, and associated law enforcement activity within OPCNM. Tortoise habitat within OPCNM is contiguous with habitat of the Cabeza Prieta NWR, the Tohono O'odham Indian Reservation, BLM land and Mexico.

Saguaro National Park outside of Tucson contains excellent habitat for desert tortoises, and tortoise populations within the park have exceeded 100 adults/sq. mi. (Robichauex and Wirt 1995-1996, Wirt et al. 1998a and 1998b, Wirt et al. 1999, Averill-Murray 2000). However, due to the close proximity of the park to a densely populated urban area, anthropogenic threats are high. NPS sponsored research determined that SDTs occupying habitat within a kilometer of the park boundary were at risk from road kill, collecting and other human impacts (Goldsmith 1990). Other potential concerns from high use of the area include introduction of non-native plants and increased risk of fire (NPS undated, Averill-Murray 2000). Tortoise habitat within the park is adjacent to habitat on Forest Service, municipal, and private land. Averill-Murray (2000) reported that community development was displacing the tortoises on private land adjacent to the park.

Lake Meade National Recreation Area contains populations of SDTs in low densities across BLM Category III habitat on the south and east side of the Colorado River (Averill-Murray 2000). The area is also home to Mojave populations of the desert tortoise. Averill-Murray (2000) reported that park policy is to treat the two populations with equal regard, thus affording the Sonoran desert tortoise within the recreation area equal protection to those enjoyed by the Mojave populations under the ESA. Despite this, heavy impacts in the recreation area pose significant threats to the tortoise populations, including illegal OHV activity, collection and poaching, and the presence of feral burros (Averill-Murray 2000).

U.S. Forest Service (USFS)

As discussed earlier, desert tortoises occupy significant portions of the Tonto and Coronado National Forests. Currently, neither of the Forest's Land and Resource Management Plan (LRMP) contains specific directions for the management of desert tortoises on public lands and both plans are outdated (Coronado NF 1986, Tonto NF 1985).

The Tonto National Forest has published a Conservation Assessment document for the desert tortoise. Written in 1993, the document is outdated but does provide "guid[ance for] Forest land and resource management activities to ensure protection and enhancement of tortoise habitat and populations [and] schedule species and habitat monitoring to assess status and trends" (TNF 1993). The plan lists threats to the tortoise on national forest lands including vandalism, OHV use, urbanization and development, livestock grazing, mining, fires and other habitat degradation and loss. Among the report's recommendations are the continued analysis (through NEPA) and revision of livestock grazing allotments to meet vegetation and utilization objectives. Unfortunately, the Forest Service has largely failed to meet its NEPA obligations with regard to livestock grazing (Table 5). The plan also recommends closure of tortoise habitat to mining and surface occupancy, restricting OHV use within habitat to designated roads and trails only (or elimination entirely in high fire danger areas), and the construction of underpasses and fencing to facilitate tortoise movements and reduce mortality (TNF 1993).

Native American Nations

The Bureau of Indian Affairs (BIA) is involved in the oversight of Indian trust lands in Arizona, some which contain desert tortoise habitat. The BIA currently does not have a management policy for the SDT, and the majority of management actions and policies regarding wildlife are left up to individual tribal governments (Averill-Murray 2000). Management of sensitive species on Indian Reservation lands has been a source of significant controversy, in part as a result of tribal sovereignty issues.

There are currently ten reservations in Arizona that contain known or potential SDT habitat: Fort Mojave, Colorado River, Hualapai, Fort McDowell, Salt River Pima-Maricopa, Gila River, Ak Chin, Tohono O'odham Nation, Pasqua Yaqui, and San Carlos. The distribution and abundance of SDTs has not been established for any reservation (Averill-Murray 2000). The largest amount of SDT habitat is thought to occur on the Tohono O'odham Nation, with substantial portions occurring on the Gila River and San Carlos Reservations.

Although no reservations conduct surveys or perform active management for Sonoran desert tortoises or their habitat, a recent program of the Tohono O'odham Nation, the Wildlife and Vegetation Management Program (WVMP), now has oversight over the desert tortoise on Tohono O'odham lands. It is likely that this program will conduct surveys to determine desert tortoise distribution and set up on going monitoring plots, given adequate funding (Averill Murray 2000).

Sonoran desert tortoise conservation on Tohono O'odham Nation and other Native American lands may be aided by the fact that some Native Americans in Arizona have a historical relationship with desert tortoises that is of important cultural and spiritual significance (Schneider 1996, Nabhan 2002). This historical relationship may provide tortoises within tribal lands with some informal protection. Ultimately, however, it is possible development and urban pressures, along with the need to increase tribal governments' revenue, will increase the frequency of conflicts over management of tortoises occurring on reservation lands. A well developed management strategy combined with sufficient funding could reduce such conflicts.

Other Federal Agencies

Additionally, the, Bureau of Reclamation and Department of Defense all have some management authority over desert tortoise habitat. As discussed earlier, the Bureau of Reclamation (BOR) manages the Central Arizona Project (CAP) and quarry operation in western Arizona, as well as Safety of Dam Repairs on CAP reservoirs and some construction activities on Indian lands related to the settlement of water-rights disputes (Averill-Murray 2000). The BOR does not currently have a management policy for the desert tortoise, but is a member of the AIDTT and a signatory on the team's 1996 management plan document. It also adheres to BLM management guidelines for the desert tortoise (BLM 1988 and 1990, AIDTT 1996, Averill-Murray 2000).

Additionally, several Department of Defense facilities manage desert tortoise habitat. The Yuma Proving grounds follows management directives from the 1996 AIDTT management plan for the desert tortoise, incorporated by reference into the Proving Ground's 1997 Integrated

Natural Resource Management Plan (US Army 1997). Tortoise populations within the Yuma Proving Ground are limited to Category III habitat in the northern sections of the Proving Ground and appear to be scattered and low-density. Impacts to desert tortoises on these lands are thought to be low, as military activities are largely confined to land and airspace south of potential tortoise habitat (Averill-Murray 2000).

The Barry M. Goldwater Range contains significant acreage of Category I habitat for the SDT, especially within the Sauceda and Sand Tank Mountains (Averill-Murray 2000). Additionally, significant Category II and III habitat is also located within the range boundary. The Goldwater Range completed a draft Integrated Natural Resources Management Plan (INRMP) and Environmental Impact Statement in 2003 (US Air Force 2003a and 2003b). The plan notes that desert tortoise sign was found in all survey areas except the Aguila Mountains (Dames and Moore 1996, US Air Force 2003b). The plan documents a likely favorable effect on the tortoise for the proposed action regarding natural resources management as it would shift the focus of protection from federally protected species to ecosystem/biodiversity management (US Air Force 2003). The plan further documents likely favorable effects on the desert tortoise from a proposed ban on roadside camping, proposed road closures and OHV regulation. The plan does acknowledge that potential negative impacts to the tortoise could occur through the implementation of site-specific actions, including the development of the proposed Cabeza Prieta NWR bypass road, but leaves such effects out of the INRMP, saying that proposed site-specific actions are to be analyzed "in detail separately pursuant to NEPA" (US Air Force 2003).

The Florence Military Reservation (FMR) also contains occupied SDT habitat. The AGFD has been studying the desert tortoises there to determine tortoise use relative to land used for military training activities (Riedle et al. 2008). However, as tortoise habitat on FMR is treated as Category III habitat where the management guideline is to limit population declines to the extent possible; and, even this tepid BLM recommendation is not binding on the reservation, it seems unlikely that protective management for tortoise populations will occur without Federal listing (Harris Environmental Group 2001).

<u>Other State and Local Agencies</u>

The Arizona State Lands Department and Pima County all have some management authority over desert tortoise habitat. The State Lands Department manages state trust land with the goal of maximizing revenue to benefit education, health and penal institutions (Averill-Murray 2000), and comprises 9.5 million acres, 13% of the state's land area. State land includes significant tortoise habitat in several areas (Averill-Murray 2000). The State Lands Department currently has no management policy for the SDT, although it is a member of the AIDTT, and works in conjunction with the AGFD to coordinate actions to minimize impacts on desert tortoises. The AGFD in turn recommends mitigation measures for tortoise impacts for which it is consulted. AGFD also comments on state land projects related to urban planning, land sales and exchanges, rights-of-way and commercial leases, although AGFD's recommendations to the State Lands Department are not binding (Averill-Murray 2000).

Pima County, which includes the cities of Tucson, South Tucson, and the towns of Oro Valley, Marana, and Sahuarita, is one of the most rapidly developing areas in the southwest. Pima County has been developing a Habitat Conservation Plan to obtain an ESA section 10(a) permit section for the last 10 years or so. Surprisingly, the original 2000 Pima County, Arizona *Draft Sonoran Desert Conservation Plan* made only cursory mention of the desert tortoise and omitted it from its list of vulnerable species within Pima County (Pima County 1999a, 1999b, and 2000). The August 2006 Draft Multispecies Conservation Plan added the Sonoran desert tortoise to the list of 55 other species already on the list of vulnerable species (Pima County 2006). The County does recognize that populations within Pima County are decreasing but the draft plan offers few specific measures related to Sonoran desert tortoise conservation in this fast-growing area.

(5) OTHER NATURAL OR MAN-MADE FACTORS AFFECTING ITS CONTINUED EXISTENCE

Off-Highway Vehicle (OHV) Use

The use of OHVs for recreation on BLM land continues to increase dramatically. Sales in all categories of OHVs - sport utility vehicles (SUVs), pickup trucks, off-road motorcycles and all-terrain vehicles (ATVs) - have increased dramatically in the last decade. ATV sales in Arizona increased by an average of 29% *per year* in the period 1995-1998 (BLM 2003).

OHV impacts can be diverse and drastic and have both direct and indirect effects (Boarman 2002). OHVs cause direct mortality by crushing tortoises and burrows that may have tortoises in them (Marlow 1974, Campbell 1985, Berry 1990 as amended, Bury and Luckenback 2002). OHVs often travel in washes, a subhabitat type where Averill-Murray and Averill-Murray (2005) found tortoises on 71% of their transects (see also Jennings 1997). OHV cause damage to the habitat by compacting the soil, which alters the plant community, reduces water infiltration rate, and changes soil temperature (Willis and Raney 1971, Babcock and Sons 1973, Davidson and Fox 1974, BLM 1975, Webb et al. 1978, Adams 1982a, 1982b, Webb 1983). Cryptogamic crusts, which have many important ecosystem functions, are easily damaged by OHVs (Belnap and Gardner 1993, DeFalco 1995, Belnap 1996). Plants are damaged, plant density reduced, and soil is lost and eroded in areas of OHV use (Davidson and Fox 1974, Luckenback 1975, Snyder et al. 1976, Wilshire and Nakata 1976, Vollmer et al. 1976,Eckert et al. 1977, Iverson 1979, Adams and Endo 1980a, 1980b, Rowlands et al. 1980, Wilshire 1980, Adams et al 1982b, Hinkley 1983, Lathrop 1983, Burge 1986, Woodman 1986, Berry et al. 1990, BLM 2001a and 2001b, Bury and Luckenback 2002).

Most importantly, three studies provide evidence that OHV use reduces tortoise density. Bury and Luckenback (2002) found 3.8 times more tortoises in an unused area compared to an adjacent OHV area. The animals were heavier, more active, and had more burrows in the non-OHV site. Berry et al. (1986) reported higher declines in tortoise densities outside an exclosure where OHV use was prevalent compared to inside a fenced exclosure. Berry et al. (1994) noted an association between low number of vehicle trails and a higher density of tortoise sign. Although not definitive, these studies support the hypothesis that OHV activity can have detrimental effects on desert tortoises.

Access to sensitive habitats by OHV users increases the probability of illegal poaching and collecting, crushing of burrows and nests, the compaction of soil, inhibition of plant growth, ignition of wildfires, and release of free-roaming dogs. Although dramatic increases in the prevalence of OHV use, particularly on public lands, has been recognized anecdotally by the BLM and is evidenced by vastly increased sales of OHVs, no good documentation exists of level of absolute usage of OHVs on public lands. Averill-Murray (2000) reported a 20% increase in OHV use on BLM land in the Kingman Resource Area for the period 1994-1999, as determined from the agency's Recreation Management Information System. BLM's Lawnet report documented 124 violations for improper vehicle use on or off roads on public land in 1998 alone, exclusive of the Arizona Strip (Averill-Murray 2000).

We examined incident reports for illegal off-roading activity within Organ Pipe Cactus National Monument for the period 2/24/1996 to 4/13/2002 and found 119 separate offenders, along with 860 speeding violations (road driving) for the period 1/5/96 to 6/14/2002 and 30 violations for destruction and damage to natural resources for the period 2/2/1999 to 4/4/2002, an undetermined amount of which were related to OHV use.

Given the documented impacts to desert tortoises from OHV use in the Mojave desert, and increasing OHV usage in the Sonoran desert, it is likely that the threat posed by OHV use to SDTs will only increase in the foreseeable future.

Fire

Wildfires within tortoise habitat have the potential to be very destructive to desert tortoise populations (Duck et al. 1994, Brooks et al. 1999, Alford 2001, Esque et al. 2002). Fires reduce the tortoise carrying capacity of the landscape by decreasing cover and forage, kill tortoises through direct exposure and suffocation, injure tortoises, affecting the viability of survivors, and convert habitats to non-tortoise friendly ecotypes (BLM 1990, Brooks et al. 1999, Duck et al. 1994, Esque et al. 2002). Additionally, fire management and suppression has been noted as a cause of tortoise mortality when individuals are crushed and burrows are destroyed by fire-fighting equipment (Duck et al 1994).

Animals whose evolution has included frequent encounters with wildfire disturbances are often predicted to benefit from fire disturbance. Desert tortoises, however, which evolved in the absence of repeated fires, are expected to experience decline (Esque et al. 2002). Tortoise habitat within the Sonoran Desert is not a historically fire-adapted community, and dominant trees, shrubs and succulents do not easily recover from fire events (Esque et al. 2002). As a result, fire forces the rapid and relatively complete conversion of desert scrub to grasslands at higher elevations and to barren landscape at lower elevations within the Arizona Uplands (BLM 1990, Esque et al. 2002). Exotic grasses burn at high temperature and can ignite and incinerate woody material they encounter, completely incinerating large areas of vegetation (Esque et al. 2002). In the Central Sonoran Desert, fire is being used to maintain the vigor of buffelgrass (Esque et al. 2002).

The introduction of fire-adapted, non-natives has resulted from human activities, primarily livestock grazing, urbanization, road building, vehicular traffic and agricultural development (BLM 1991, Fleischner 1994, Esque et al. 2002). Alford (2001) noted an increase in number of fires in the Sonoran Desert during the past half-century, correlated with an increase in auto traffic along major highways. Indeed, the "Mother's Day Fire" of 1994 started when overheated brakes from an automobile ignited invasive red brome (*Bromus rubens*) (Esque et al. 2002). The fire burned 1,100 acres within Saguaro National Park before it was contained.

Fire history data from the Coronado National Forest confirms that human-caused fires account for a large percentage of the total number of wildfires in southeastern Arizona (Figure 7). For the period 1985-1999, a total of 2,520 fires were recorded within the forest boundary, including 1,164, or 46%, human-caused fires with the rest attributed to lightning (Figure 7). Vehicles were the confirmed cause of 30 fires. The total acreage affected by all fires for the same period was 277,572 acres, with human-caused fires accounting for 67,953 acres, or 24% of the total burned acreage. Within USGS 7.5' quadrangles known to contain desert tortoise occurrences, a total of 530 fires were recorded, with 259 fires, or 49%, caused by humans and the rest attributed to lightning. A total of 82,478 acres were burned within areas of known desert tortoise occurrences, with human caused fires accounting for 8,330 acres, or 10% of the total burned acreage within desert tortoise habitat.

It should be noted that some of the fire-impacted acreage noted above may have been forested habitat adjacent to desert tortoise habitat. However, it is clear that simply trying to

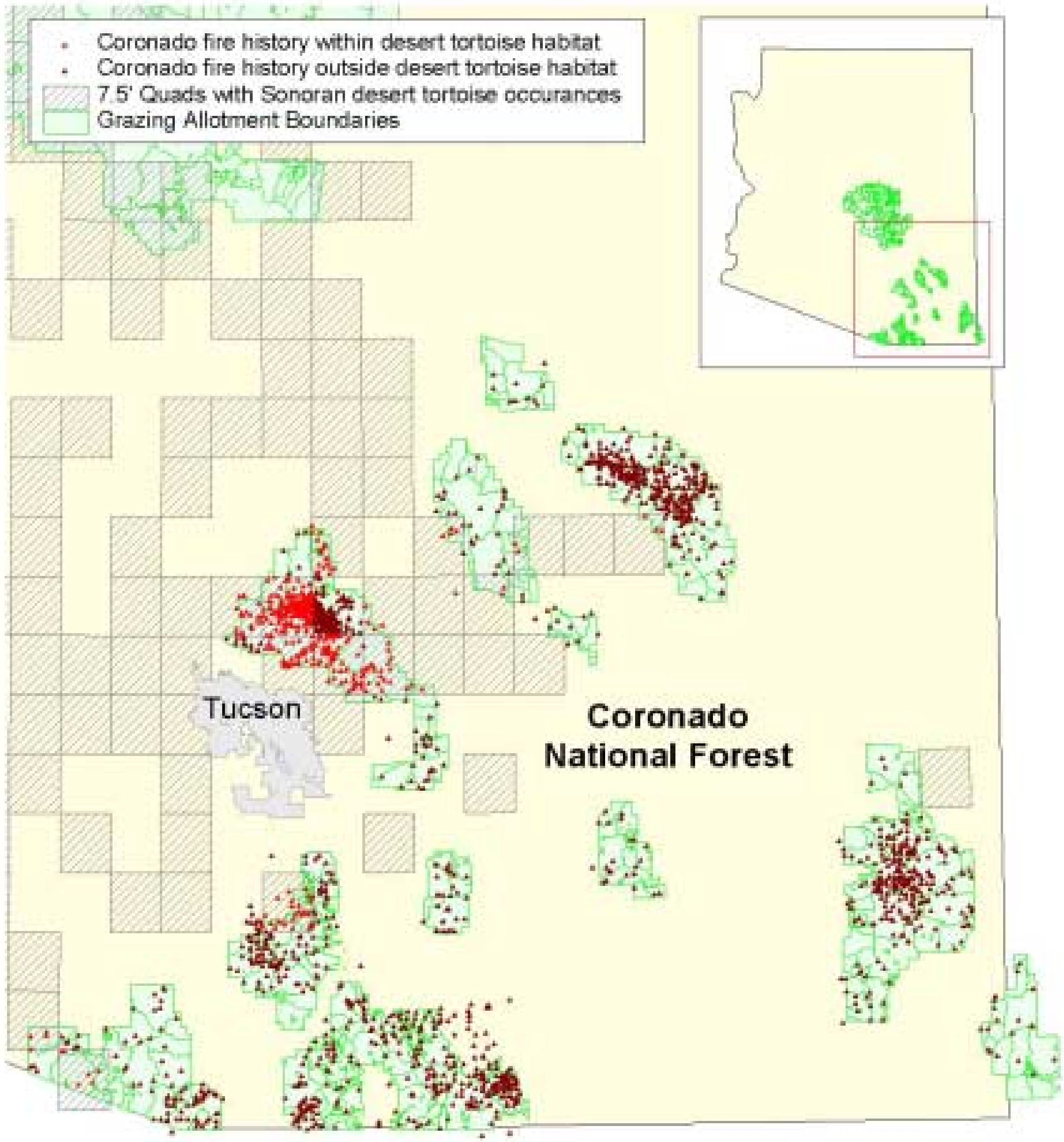

Figure 7. Fire history for the Coronado National Forest 1985-1999. A total of 2,520 fires have been reported within the Coronado National Forest for the period 1985-1999, affecting 277,572 acres. Of these, 530 fires occurred within areas known to be occupied by desert tortoises and affected 82,478 acres.

prevent human caused fires will not be enough to prevent loss of tortoises to fire disasters, but rather the effort must be made to eliminate the root cause of catastrophic fires in the southern Sonoran Desert: fire-adapted non-native vegetation, and proliferation of vehicles and recreation activities within sensitive tortoise habitat.

Within the Sonoran Desert, studies have confirmed high mortality rates among tortoises caught in wildfires. A total of 14 dead and 9 live tortoises were found at four post-burn study sites (Esque et al. 2003). Fire-related-injuries to and mortality to of SDT's has also been documented elsewhere (Esque et al. 2002). Notably, the loss of female tortoises to fire may be greater than that of males, as peak fire season occurs during the arid months of June-August, when males often remain dormant in shelters (Esque et al. 2002). Thus, there may be long-term effects on population demographics due to decreased population fecundity, as well as loss of habitat and decreased habitat quality.

Roads

Paved and dirt roads criss-cross desert tortoise habitat throughout Arizona. Few tortoise populations live far enough from roads to be immune to their effects. Roads have many potential effects, both direct and indirect. The primary direct impact is from deaths caused by being crushed (road kill). On one California State Highway in the west Mojave Desert, a conservative estimate is that one tortoise is killed every 2 miles per year (Boarman and Sazaki 1996). The mortality results in a depression zone within at least ½ mile of highways where few tortoises live (Boarman et al. 2006). These results are from Mojave tortoises that generally live in more open valleys, where more highways tend to occur, than do tortoises in the Sonoran Desert, so the results are not directly comparable.

Unfenced highways, roads and routes fragment the habitat, isolate tortoises and may result in losses of tortoises on a large scale (USFWS 1994b, Boarman 2002). While barrier fencing along major roads may help curtail tortoise loss on roads, barrier fencing itself may increase fragmentation effects (Boarman 2002). This is of particular significance for SDTs since as discussed above, movement between ranges may be essential to preserve genetic heterogeneity and allow for reestablishment following local extirpations (Edwards et al. 2004). Even small dirt roads through habitat may place tortoises at direct risk (von Seckendorff Hoff and Marlow 2002). Boarman and Kristin (2008) identify roads as one of the most prevalent threats on the SDT study plots they reviewed.

There are indirect impacts of roads, also. Roads provide food for ravens, which tend to nest near the roads (Knight and Kawashima 1993, Boarman 1993). The flush of vegetation that occurs near road edges may attract tortoises, but it also puts them in greater harm by foraging close to the traffic and in areas where cars may pull off the road and crush them (Frenkel 1970, Johnson et al. 1975). Contaminants from exhaust and tire wear may be introduced into soil and food and ultimately eaten by tortoises. There is some evidence that these contaminants are elevated in tortoise tissues and may cause harm (Homer et al. 1998). Roads also facilitate access by people to tortoise habitat and such access increases the probability that other activities potentially harmful to tortoises may occur.

Drought and Climate Change

Drought

Drought should be considered an additional threat to the Sonoran desert tortoise. Having evolved in an arid region, desert tortoises have a variety of adaptive responses to drought, as we have discussed in the Section on Life History above. Summer monsoons are extremely important, as during this rainy period desert tortoises can drink, flush their bladders, re-hydrate and maximize their energy balance by intensive vegetation browsing (Duda et al. 1999, Averill-Murray 2000). Varying precipitation levels significantly impact desert tortoise movement and activity patterns (Duda et al. 1999). Prolonged drought leads to physiological stress among tortoises, which are then likely to remain inactive in order to conserve water (Duda et al. 1999). Drought can cause desert tortoise mortality from dehydration and starvation, as documented in the Mojave desert tortoise (Peterson 1994).

Drought can negatively impact tortoise reproduction. As discussed in the Life History section, low mating activity during the previous year due to drought or decreased forage availability can lead to decreased clutch sizes and/or a lower proportion of reproductive females even if the current year's precipitation and forage availability is favorable (Nagy and Medica 1986, Averill-Murray and Klug 2000, Klug and Averill-Murray 1999, Murray et al. 1996). Dry years can also lead to lower rates of juvenile survivorship and recruitment and potential losses of tortoise cohorts (Averill-Murray et al. 2002b). Wirt and Holm (1997) found that two of six female Sonoran desert tortoises laid eggs after ten years of drought in the Maricopa Mountains in 1994, while all seven female tortoises laid eggs at another site that was apparently less impacted by drought. The population decline documented in the Maricopa Mountains may be caused by drought (Wirt and Holm 1997, AIDTT 2000, Averill-Murray et al. 2002b).[5]

In addition to the direct threat from drought, this threat can act synergistically and cumulatively with other threats, particularly disease, to cause population declines. As we discussed in the section on livestock grazing above, cattle may remove enough forage in years of low-precipitation to reduce desert tortoise reproductive output (Tracy 1996). Both the BLM and

[5]AIDTT (2000) also suggested feral dogs may be the cause of this population decline.

USFS are failing to manage their livestock grazing programs in a way that mitigates the impact on desert tortoises from livestock grazing during drought years.

While Averill-Murray et al. (2002a) noted that variation in amount and timing of rainfall and resulting plant growth restricts desert tortoises' ability to obtain required energy for maintenance, growth, and reproduction, they also noted that more research is needed to understand the degree to which rainfall impacts desert tortoises.

Climate Change

There are indications that portions of the western United States may be entering into a multi-decadal period of drought. Recent studies have shown that a combination of cool tropical Pacific sea surface temperatures, combined with warm North Atlantic sea surface temperatures result in the persistence of multi-year drought. Such a combination of factors is believed to be responsible for the drought period in the 1950's. In 1995, the North Atlantic sea surface temperatures became warm, and in 1998, the Tropical Pacific sea surface temperatures became cool. Since 1999, drought conditions (severe or extreme in many areas) have persisted over much of the western United States. Shifts in sea surface temperatures from cool to warm and vice versa, tend to last for multi-decadal periods (Betancourt 2004). Based on these observations Betancourt (2004) believes the West will face drought conditions for years to come.

There is now strong scientific evidence that anthropogenic releases of greenhouse gases are altering the global climate. Although prediction of specific regional effects is still in its infancy, the best available scientific data suggest dramatic changes in climate within the range of the SDT, which will further stress populations already facing numerous threats to their existence. Climate change may have already resulted in a measurable increase in minimum winter temperatures in the Sonoran Desert (Weiss and Overpeck 2005).

The US National Assessment of the Potential Consequences of Climate Variability and Change conducted regional assessments of the predicted impacts of climate change on various regions of the United States. The assessment for the Southwestern U.S. was:

> An overall increase in average annual temperatures of 1.1º C to 1.7º C (2º to 3º F) has been detected over the past century. Average annual precipitation changes over the same period have been variable, with rainfall increases in southern Nevada, Utah, New Mexico, and central Arizona. *Rainfall decreases have been measured in southeastern California*, *southern Arizona*, and the central Rockies within the region's highly developed water delivery systems.[6]

In predictions of future climate change, there would be an increased frequency of both extreme rainfall events and drought. There would be increased year-to-year variability in precipitation. Increases in temperature, coupled with altered precipitation regimes, would cause as yet unknown changes in both species composition and extent of various habitats, and impacts on SDTs. While the exact effects of climate change are yet to determined, the alterations to habitat will likely further stress already at risk SDT populations.

In addition, climate change interacts with fire. According to the National Assessment,

> Fire hazard potential will increase if projected warming occurs in the Southwest accompanied by sequences of wet and dry periods optimal for fuel production. Such would be the case, for example, with El Niño and La Niña cycles.[7]

Research on the Mojave population indicates that the physiological and behavioral flexibility of desert tortoises appears central to their ability to survive droughts and benefit from periods of resource abundance (Henen et al., 1998). The latter workers observed strong effects of the El Nino (ENSO) weather patterns on tortoise survival and suggested that local manifestations of global climate events could have a long-term influence on the tortoise populations there. In addition to inducing more extreme physiological stresses, as discussed above changes in average

[6]See Southwestern Assessment Executive Summary at p. 3. On-line at: http://www.ispe.arizona.edu/research/swassess/pdf/chapter1.pdf.
[7]Ibid. at p. 4.

summer temperatures could impact hatchling survival and sex ratios since desert tortoises have environmental sex determination.

In sum, both drought and climate change present additional stresses to Sonoran desert tortoises, on their own, as well as in concert with other anthropogenic threats (e.g., livestock grazing, and urban sprawl).

VIII. CONCLUSIONS

Sonoran desert tortoises (*Gopherus agassizii*) are increasingly impacted by urbanization and human activities throughout Arizona. Density estimates of tortoises in Arizona indicate that tortoise numbers have dropped precipitously throughout their range, in some cases dramatically (Boarman and Kristan 2007). The principal reasons for these downward trends are likely similar to those affecting the Mojave population: a death of a thousand cuts (Tracy et al. 2005). Effects of disease, livestock grazing, mining, urbanization and development have all been documented within desert tortoise habitat in Arizona and appear to be accelerating at the present time.

As the primary manager of Sonoran desert tortoise habitat, the Arizona BLM is facing an increasingly uphill battle to prevent further tortoise declines. Unfortunately, staff resources and funding are likely to be inadequate for the agency to meet its commitment of maintaining viable populations of tortoises within Category I and II habitat, as evidenced by the recent drastic population declines throughout its range. Agency compliance with NEPA as it relates to grazing allotments has been poor, both within the BLM and the Forest Service, the effects of which cannot be underestimated, due to the ubiquity of grazing within tortoise habitat on public lands (Tables 3, 4 & 5). Additionally, BLM Resource Management Plans and Forest Service Land and Resource Management Plans are woefully out of date, and because of this, fail to reflect the conservation needs of the tortoise today.

The AGFD continues to bear a majority of the burden for monitoring and assessing the status and threats facing the SDT. If declines in tortoise populations are to be addressed and population recovery is to be affected, additional management actions are necessary from the BLM and USFS, as well as the other agencies involved more peripherally in the management of the desert tortoise. As is demonstrated in this petition, adequate protection has not occurred on federal lands, which underscores the need for ESA listing.

SDT populations are clearly facing a greater risk today than they were at the time of Barrett and Johnson's 1990 status review or Averill-Murray's 2000 status review update. Regardless of the eventual remedy, it is clear that current conservation actions on behalf of the tortoise are not adequate to ensure stable populations in Arizona. Particularly because of the long survey intervals at monitoring sites and the inability to detect and correct catastrophic declines, it is vital that land managers and other responsible agencies address the problem of tortoise decline in Arizona or we risk future local or rangewide extinction.

Given documented significant declines in SDT populations, and the lack of proactive management by government agencies, it is clear that the SDT warrants protection under the ESA. Based on morphological and ecological divergence, as supported by genetic analysis, the SDT clearly meets the DPS requirements of the USFWS, and as such, can be considered a distinct population segment for ESA listing purposes.

REQUESTED DESIGNATION

WildEarth Guardians and Western Watersheds Project hereby petition the U.S. Fish and Wildlife Service under the Department of Interior to list the Sonoran desert tortoise (*Gopherus agassizii*) as an Endangered or a Threatened species pursuant to the Endangered Species Act. This listing action is warranted, given the imperiled biological status of this taxon. The Sonoran desert tortoise is threatened by all the factors that USFWS must consider in assessing whether a species qualifies for listing under the Endangered Species Act. As such, we request expeditious listing of the Sonoran desert tortoise as a Threatened or Endangered Species under the ESA.

NEED FOR ECOSYSTEM MANAGEMENT

Petitioners believe that classification of the SDT as an Endangered or Threatened species under the ESA will ensure that state and federal agencies develop an effective form of ecosystem protection. For example, protection of desert tortoise burrows will provide protection for snakes, lizards, rodents, javelinas, birds, insects, and other invertebrates who use tortoise burrows for refugia (Averill-Murray et al. 2002a). More broadly, the SDT can play an umbrella role,[8] in that protection of its habitat can safeguard other species which share that habitat.

The efficiency of such management has been noted by scientists and USFWS itself (GAO 1994; Noss et al. 1995; Benedict et al. 1996). Moreover, the protection of ecosystems is stated as the very purpose of the ESA. Where single species play umbrella roles, the ESA's single-species protection provisions can correlate to ecosystem-wide protection. Since the desert tortoise likely serves as an umbrella species (Brooks 2000), the Sonoran desert tortoise's listing as Endangered or Threatened should be among USFWS's highest priorities.

CRITICAL HABITAT

The ESA mandates that, when the USFWS lists a species as endangered or threatened, the agency generally must also concurrently designate critical habitat for that species. [16 U.S.C. § 1533(a)(3)(A)(i) and § 1533(b)(6)(C)] Accordingly, Petitioners request that critical habitat be designated for the SDT concurrent with final ESA listing.

Petitioners expect that USFWS will comply with its mandate and designate critical habitat concurrently with the listing of the Sonoran desert tortoise DPS. We believe that all

[8] An umbrella species is a taxon which requires extensive habitat and therefore, protection of its habitat provides umbrella protection for other wildlife and plants using that habitat (Miller et al. 1998/99). The Sonoran Desert Tortoise has extensive habitat needs. For example, Howland and Rorabaugh (2002) estimate that a viable population would require about 2,590-7770 sq. km. of suitable habitat.

current and historic occupied habitat and inter-range dispersal habitat meet the criteria for designation as critical habitat and must therefore be designated as such.

IX. LITERATURE CITED

Alford EJ. 2001. The effects of fire on Sonoran desert plant communities. Doctoral Dissertation, Arizona State University.

Anderson DR, Burnham KP, Lubow B and Thomas LJ. 1998. Desert tortoise population monitoring concepts and field application, a technical workshop with an emphasis on assumptions, field protocol and sampling for range-wide surveys. Unpublished.

Anderson DR, Burnham KP, Lubow BC, Thomas L, Corn PS, Medica PA and Marlow RW. 2001. Field trials of line transect methods applied to estimation of desert tortoise abundance. Journal of Wildlife Management 65(3): 583-597

Arizona Game and Fish Department. 1990. Interim techniques handbook for collecting and analyzing data on desert tortoise populations and habitats. Arizona Game and Fish Department, California state resource agencies, Nevada Division of Wildlife, Utah Division of Wildlife Resources United States Department of the Interior, Bureau of Land Management, Fish and Wildlife Service.

Arizona Game and Fish Department. 1996. Protocols for handling free-ranging Sonoran desert tortoises. Arizona Game and Fish Department, California State Natural Resources, National Biological Service, Kofa National Wildlife Refuge, US Air Force, US Marine Corps, Yuma Proving Grounds, Nevada Department of Wildlife, Utah Division of Wildlife Resources, US Bureau of Indian Affairs, Bureau of Land Management, US Bureau of Reclamation and US Fish and Wildlife Service.

Arizona Game and Fish Department. 2000. Mitigating impacts to desert tortoise in Arizona supplemental guidance.

Arizona Game and Fish Department. 2004. Desert Tortoise Management. On Arizona Game and Fish Department Conservation and Management website.

Arizona Game and Fish Department. In preparation. Wildlife of special concern in Arizona. Arizona Game and Fish Department Publication. Phoenix, Arizona. 32 pp.

Arizona Heritage Data Management System. 2008. Element Occurrences of desert tortoises in Arizona by USGS 7.5' quad. Database.

Arizona Interagency Desert Tortoise Team. 1994. Memorandum of understanding for Arizona desert tortoise management. Arizona Interagency desert tortoise team.

Arizona Interagency Desert Tortoise Team. 1996. Murray RC and Dickinson V, eds. Management plan for the Sonoran desert population of the desert tortoise in Arizona. Arizona Interagency Desert Tortoise Team.

Arizona Interagency Desert Tortoise Team. 1997. Recommend standard mitigation measures for projects in Sonoran desert tortoise habitat. Draft Copy. 7p.

Arizona Interagency Desert Tortoise Team. 2000. Averill-Murray, RC ed. Status of the Sonoran population of the desert tortoise in Arizona: an update. Arizona Interagency Desert Tortoise Team and Arizona Game and Fish Department, Phoenix. 48 pp.

Arizona Interagency Desert Tortoise Team. 2003. Need for state conservation strategy and agreement for the Sonoran desert tortoise. A presentation by the Arizona Interagency Desert Tortoise Team. http://www.swstrategy.org/rec/REC_Meeting_Minutes/Mar_03/Apdx_4_Sonoran_Desert_Tortoise.pdf Retrieved July 2004.

Averill-Murray RC. 2000. Survey protocol for Sonoran desert tortoise monitoring plots: reviewed and revised. Arizona Interagency Desert Tortoise Team.

Averill-Murray RC and Klug CM. 2000. Monitoring and ecology of Sonoran desert tortoises in Arizona. Technical Report 161, Nongame and Endangered Wildlife Program, Arizona Game and Fish Department: Phoenix, Arizona.

Averill-Murray RC and Swann DE. 2002. Impacts of urbanization on desert tortoises at saguaro national park: tortoise density along the southern park boundary. Technical Report 199. Nongame and endangered Wildlife Program, Arizona Game and Fish Department. Phoenix, Arizona.

Averill-Murray RC, Martin BE, Bailey SJ and Wirt EB. 2002a. Activity and behavior of the Sonoran desert tortoise in Arizona. In Van Devender TR editor. The Sonoran Desert Tortoise: natural history, biology, and conservation. Tucson, Arizona: The University of Arizona Press. pp. 135-158.

Averill-Murray RC, Woodman AP, and Howland JM. 2002b. Population Ecology of the Sonoran Desert tortoise in Arizona. In Van Devender TR editor. The Sonoran Desert Tortoise: natural history, biology, and conservation. pp. 109-134. Tucson, Arizona: The University of Arizona Press.

Avery HW. 1998. Nutritional ecology of the desert tortoise (Gopherus agassizii) in relation to cattle grazing in the Mojave Desert. Ph.D. Dissertation, Department of Biology, University of California, Los Angeles. 158 pp.

Bailey SJ, Schwalbe CR, and Lowe CH. 1995. Hibernaculum use by a population of desert tortoises (*Gopherus agassizii*) in the Sonoran Desert. Journal of Herpetology 29(3): 361-369

Barrett SL. 1990. Home range and habitat of the desert tortoise (*Xerobates agassizii*) in the Picacho mountains of Arizona. Herpetologica 46(2): 202-206.

Barrett SL and Johnson TB. 1990. Status summary for the desert tortoise in the Sonoran Desert. Unpublished report to US Fish and Wildlife Service, Albuquerque, New Mexico.

Barrett SL, Humphrey JA and Harper SD. 1990. Desert tortoise reintroduction and mitigation assessment study. Final report. Prepared for Bureau of Reclamation, Arizona Projects Office, Central Arizona Project; Phoenix, Arizona.

Berry KH. 1978. Livestock grazing and the desert tortoise. North American Wildlife and Natural Resources Conference Transactions 43: 745-750

Berry KH. 1984. A description and comparison of field methods used in studying and censuring the desert tortoises. In Berry KH editor, Status of the desert tortoise *Gopherus agassizii*) in the United States. Report to the USFWS from the Desert Tortoise Council, Order No. 11310-0083-81.

Berry KH. 1986a. Desert tortoise (*Gopherus agassizi*) relocation: implications of social behavior and movements. Herpetologica 42(1): 113-125

Berry KH and Christopher MM. 2001. Guidelines for the field evaluation of desert tortoise health and disease. Journal of Wildlife Diseases 37(3): 427-450.

Berry KH, Jones R, and Scientists. Highlights from the November 2002 Workshop on Desert Tortoise: What We Know; What We Suspect; Research Priorities: What We Need to Know for Recovery and Management Priorities. 16pp.

Berry KH, Morafka DJ and Murphy RW. 2002. Defining the desert tortoise(s): our first priority for a coherent conservation strategy. Chelonian Conservation and Biology 4: 249-262.

Betancourt JL. 2004. The current drought (1999-2003) in Historical Perspective. Unpublished paper, Desert Laboratory, U.S. Geological Survey & University of Arizona.

Bjurlin CD and Bissonette JA. 2004. Survival during early life stages of the desert tortoise (*Gopherus agassizii*) in the south-central Mojave Desert. Journal of Herpetology 38(4): 527-535.

Boarman WI and Berry KH. 1995. Common Ravens in the Southwestern United States, 1968-92. Pp.73-75 *in* Our living resources: A report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems (E. T. Laroe., ed.). U.S. Department of the Interior--National Biological Service, Washington D.C.

Boarman WI. 1996. Effectiveness of fences and culverts for protecting desert tortoises along California State highway 58: 1995 report to USFWS. Desert Tortoise Research Project., Midcontinent Ecological Science Center, National Biological Service: Riverside California.

Boarman WI. 2002a. Reducing predation by common ravens on desert tortoises in the Mojave and Colorado Deserts. Prepared by the U.S. Geological Survey for the West Mojave planning team, Bureau of Land Management

Boarman WI. 2002b. Threats to desert tortoise populations: a critical review of the literature. Prepared by the U.S. Geological Survey for the West Mojave planning team, Bureau of Land Management

Boarman WI and Kristan III, WB. 2008. Status of Sonoran Desert Tortoise Populations in Arizona. Unpublished report. 40 pp. (Appendix 3 of this Petition)

Booth K. 1958. Development of eggs and young of desert tortoise. Herpetologica 13: 261-263

Bostick V. 1990. The desert tortoise in relation to cattle grazing. Rangelands 12(3): 149-151

Brooks ML, Esque TC and Schwalbe CR. 1999. Effects of exotic grasses via wildfire on desert tortoises and their habitat. Proceedings of the desert tortoise council symposium 1999: 40-41.

Brooks ML. 1995. Benefits of protective fencing to plant and rodent communities of the western Mojave desert, California. Environmental Management 19(1): 65-74

Brooks ML. 1999. Effects of protective fencing on birds, lizards and black-tailed hares in the western Mojave Desert. Environmental Management 23(3): 387-400

Brooks ML. 2000. Does Protection of Desert Tortoise Habitat Generate Other Ecological Benefits in the Mojave Desert? Pages 68-73 in McCool, S. F., D. N. Cole, W. T. Borrie, and J. O'Loughlin (eds), Wilderness Science: In a Time of Change Conference, Volume 3: Wilderness as a place for scientific inquiry, Missoula, MT, May 23-27 1999. RMRS-P-15_VOL-3.

Brown K. 2000. Ecosystem recovery: ecologists spar over population counts of threatened desert tortoise. Science 290(5489): 36.

Brown MB, Schumacher IM, Klein PA, Harris K, Correll T and Jacobson ER. 1994. *Mycoplasma agassizii* causes upper respiratory tract disease in the desert tortoises. Infection and immunity 62(10): 4580-4586.

Brown MB, Berry KH, Schumacher IM, Nagy KA, Christopher MM and Klein PA. 1999a. Seroepidemiology of upper respiratory tract disease in the desert tortoise in the western Mojave desert of California. Journal of Wildlife Diseases 35(4): 716-727

Brown MB, McLaughlin GS, Klein PA, Crenshaw BC, Schumacher IM, Brown DR and Jacobson ER. 1999b. Upper respiratory tract disease in the gopher tortoise in caused by Mycoplasma agassizii. Journal of Clinical Microbiology 37(7): 2262-2269.

Brown MB, Brown DR, Klein PA, McLaughlin GS, Schumacher IM, Jacobson ER, Adams HP and Tully JG. 2001. *Mycoplasma agassizii* sp. nov., isolated from the upper respiratory tract of the desert tortoise (*Gopherus agassizii*) and the gopher tortoise (*Gopherus polyphemus*). International Journal of Systematic and Evolutionary Microbiology 51: 413-418.

Brown, DR, Merritt, JL, Jacobson, ER, Klein, PA, Tully JG and Brown MB. 2004. *Mycoplasma testudineum* sp. nov., from a desert tortoise (*Gopherus agassizii*) with upper respiratory tract disease. International Journal of Systematic and Evolutionary Microbiology 54: 1527–1529.

Brown MB, Berry KH, Meléndez Torres C, Hasskamp MA, Wendland L, Demcovitz D, Villa Andrade MF, Schwalbe C, and Méndez de la Cruz FR. 2006. Health Status of Wild and Captive Desert Tortoises from the Hermosillo and Alamos Areas of Mexico. Abstracts of the 31st Annual Desert Tortoise Council Symposium, Tucson, Arizona. pp 5-6.

Bulova SJ. 2002. How temperature, humidity, and burrow selection affect evaporative water loss in desert tortoises. Journal of Thermal Biology 27: 175-189

Bulova, S. J. 1994. Patterns of burrow use by desert tortoises: Gender differences and seasonal trends. Herpetological Monographs. 8: 133-143.

Bureau of Land Management. 1987. Management of desert tortoise habitat: a report to the chief, Division of Wildlife and Fisheries. United States Department of the Interior, Bureau of Land Management. Washington, D.C. 52pp.

Bureau of Land Management. 1988. Desert tortoise habitat management on the public lands a rangewide plan. United States Department of the Interior, Bureau of Land Management. 23pp.

Bureau of Land Management 1989. Environmental Assessment for the Whitecliff Mining Plan. Safford, Arizona. 7pp.

Bureau of Land Management. 1990. Strategy for desert tortoise habitat management on public lands in Arizona. Arizona State Office, Bureau of Land Management, Department of the Interior.

Bureau of Land Management. 1991. Compensation for the desert tortoise. A Report prepared for the Desert Tortoise Management Oversight Group by the Desert Tortoise Compensation Team. Bureau of Land Management, Department of the Interior.

Bureau of Land Management. 1991. Biological evaluation: livestock grazing in desert tortoise habitat. Prepared by Bureau of Land Management, Arizona Strip District, Shivwits Resource Area.

Bureau of Land Management. 1997. Arizona standards for rangeland health and guidelines for grazing administration. United States Department of the Interior, Arizona Bureau of Land Management.

Bureau of Land Management. 2001a. National management strategy for motorized off-highway vehicle use on public lands. United States Department of the Interior, Bureau of Land Management, Washington D.C. 48pp.

Bureau of Land Management. 2001b. Montana State Office and Forest Service Northern Region. Off-Highway Vehicle Environmental Impact Statement and Proposed Plan Amendment for Montana, North Dakota and Portions of South Dakota.

Bureau of Land Management. 2003. St. George Field Office, Utah BLM. Environmental Assessment for the Ft. Pierce Ridge Trail Designation (UT-100-3-EA-04).

Department of Energy and Bureau of Land Management. 2008. Notice of Intent To Prepare a Programmatic Environmental Impact Statement To Evaluate Solar Energy Development, Develop and Implement Agency-Specific Programs, Conduct Public Scoping Meetings, Amend Relevant Agency Land Use Plans, and Provide Notice of Proposed Planning Criteria. Federal Register 73(104): 30908-30912.

Bureau of Reclamation. 1985. New Waddell dam design modifications, final environmental assessment. Bureau of Reclamation, Arizona Projects Office

Bureau of Reclamation. 1996. Description and assessment of operations, maintenance and sensitive species of the lower Colorado river. Final biological assessment prepared for US Fish and Wildlife Service and Lower Colorado River Multi-species Conservation Program 207 pp.

Bureau of Reclamation. 1996. New Waddell dam, Lake Pleasant regional park, master recreation plan, draft environmental assessment. Bureau of Reclamation, Lower Colorado Region, Phoenix Area Office.

Bureau of Reclamation. 1997. Final biological opinion for construction and operation of one quarry and the operation of eight existing quarries, Arizona and California. Department of the Interior, Bureau of Reclamation, Lower Colorado Regional Office.

Bureau of Reclamation. 1998. New Waddell dam, Lake Pleasant regional park, master recreation plan, supplement to the final environmental assessment. Bureau of Reclamation, Lower Colorado Region, Phoenix Area Office.

Burge BL. 1980. Survey of the present distribution of the desert tortoise, *Gopherus agassizii*, in the Kofa National Wildlife Refuge, Yuma County, Arizona. Prepared for US Fish and Wildlife Service, Kofa National Wildlife Refuge, Yuma Country, Arizona.

Burge BL. 1989. What goes up must come down. Massive balloon releases are a potential threat to tortoises and other wildlife. Tortoise Tracks 10: 4.

Bury RB, Germano DJ, Van Devender TR and Martin BE. 2002. The desert tortoise in Mexico: distribution, ecology, and conservation. In Van Devender TR editor. The Sonoran Desert Tortoise: natural history, biology, and conservation. pp. 86-108. Tucson, Arizona: The University of Arizona Press.

Bury RH, Esque TC, Defalco LA and Medica PA. 1994. Distribution, habitat use, and protection of the desert tortoise in the eastern Mojave Desert. In Bury, RB and DJ Germano, editors. Biology of North American Tortoises. National Biological Survey, Fish and Wildlife Research 13.

Carter J. 2008. Updating the animal unit month. Revised March 17, 2008. Western Watersheds Project Unpublished Report. 7 pp.

CH2MHILL. 1996a. Biological assessment of lower Colorado river quarry sites operated by the US Bureau of Reclamation. Prepared for US Fish and Wildlife Service

CH2MHILL. 1996b. Biological assessment of Palo Verde quarry site on the lower Colorado river operated by the US Bureau of Reclamation. Prepared for US Fish and Wildlife Service

Christopher MM. 1999. Physical and biochemical abnormalities associated with prolonged entrapment in a desert tortoise. Journal of Wildlife Diseases 35(2): 361-366

Cordery TE, Duck TA, Esque TC and Slack JJ. Vegetation needs of the desert tortoise (*Gopherus agassizii*) in the Sonoran and Mojave Deserts. Unpublished manuscript.

Coronado National Forest. 1986. Land and Resource Management Plan for the Coronado National Forest, as amended. U.S. Department of Agriculture, Forest Service, Southwestern Region, Denver, CO.

Council on Environmental Quality. 1979. Off-road vehicles on public lands. US Government Printing Office. Washington, D.C.

Curtin AJ. 2006. Bone Growth Strategies and Skeletochronological Age Estimates of Desert Tortoise (*Gopherus agassizii*) Populations. Ph.D. Thesis. Drexel University. 180 pp.

Dames and Moore. 1996. Sensitive species surveys on the Barry M. Goldwater Range. Final Report. Prepared for 56 CES/CEVN, Luke Air Force Base, Arizona. Contract No. DACW45-93-D-0021

Desert Tortoise Recovery Team. 1993. Proposed desert wildlife management areas for recovery of the Mojave population of the desert tortoise. Prepared for Regions 1,2 and 6 of the US Fish and Wildlife Service.

Dickinson VM, Duck T, Schwalbe CR, Jarchow JL and Trueblood MH. 2001. Nasal and cloacal bacteria in free ranging desert tortoises from the western United States. Journal of Wildlife Diseases 37(2): 252-257

Dickinson VM, Jarchow JL and Trueblood MH. 1996. Health studies of free-ranging Sonoran desert tortoises in Arizona. Final Report. Arizona Game and Fish Department, Research Branch, Technical Report #24.

Dickinson VM, Jarchow JL, Trueblood MH and JC Devos. 2002. Are free-ranging Sonoran Desert tortoises healthy? In Van Devender TR editor. The Sonoran Desert Tortoise: natural history, biology, and conservation. pp. 242-264. Tucson, Arizona: The University of Arizona Press.

Dickinson VM, Schumacher IM, Jarchow JL, Duck T and Schwalbe CR. 2005. Mycoplasmosis in free-ranging desert tortoises in Utah and Arizona. Journal of Wildlife Diseases 41(4): 839-842.

Doak D, Kareiva P, Klepetka B. 1994. Modeling population viability for the desert tortoise in the Western Mojave Desert. Ecological Applications. 4(3), 446–460.

Duck TA, Esque TC and Hughes TJ. 1994. Fighting wildfire in desert tortoise habitat: considerations for land managers. Modified from the proceedings of the 1994 Symposium of the Desert Tortoise Council.

Duda JJ, Krzysik AJ and Freilich JE. 1999. Effects of drought on desert tortoise movement and activity. Journal of Wildlife Management 63(4): 1181-1192

Edwards, T., Schwalbe, C. R., Swann, D. E., and Goldberg, C. S. 2004. Implications of anthropogenic landscape change on inter-population movements of the desert tortoise (*Gopherus agassizii*). Conservation Genetics 5: 485–499.

Esque TC and Peters EL. 1994. Ingestion of bones, stones, and soil by desert tortoises. In Bury, RB and DJ Germano, editors. Biology of North American Tortoises. National Biological Survey, Fish and Wildlife Research 13.

Esque TC, Burquez AM, Van Devender TR, Anning PJ and MJ Nijhuis. 2002. Fire ecology of the Sonoran Desert tortoise. In Van Devender TR editor. The Sonoran Desert Tortoise: natural history, biology, and conservation. pp. 312-333. Tucson, Arizona: The University of Arizona Press.

Esque TC, Schwalbe CR, Defalco, LA, Duncan RB and Hughes TJ. 2003. Effects of desert wildfires on desert tortoise (*Gopherus agassizii*) and other small vertebrates. The Southwestern Naturalist, 48(1): 103-111.

Fowler ME. 1977. Respiratory disease in desert tortoises. In Annual Proceedings of the American Association of Zoo Veterinarians, pp. 79–99.

Fleischner TL. 1994. Ecological costs of livestock grazing in western North America. Conservation Biology 8(3): 629-644.

Freilich JE and LaRue EL. 1998. Importance of observer experience in finding desert tortoises. Journal of Wildlife Management 62(2): 590-596.

Freilich JE, Burnham KP, Collins CM, and Garry CA. 2000. Factors affecting population assessments of desert tortoises. Conservation Biology 14(5): 1479-1489.

Fritts TH and Jennings RD. 1994. Distribution, habitat use and status of the desert tortoise in Mexico. In Bury, RB and DJ Germano, editors. Biology of North American Tortoises. National Biological Survey, Fish and Wildlife Research 13.

Germano DJ. 1992. Longevity and age-size relationships of populations of desert tortoises. Copeia 1992(2): 367-374.

Germano D J. 1993. Shell morphology of North American tortoises. American Midland Naturalist 129: 319-335.

Germano DJ. 1994. Growth and age at maturity of North American tortoises in relation to regional climates. Canadian Journal of Zoology 72: 918-931.

Germano DJ. 1998. Scutes and age determination of desert tortoises revisited. Copeia 1998(2): 482-4.

Germano DJ, Bury RB, Esque TC, Fritts TH and Medica PA. 1994. Range and habitats of the desert tortoise. In Bury RB and DJ Germano, editors. Biology of North American Tortoises. National Biological Survey, Fish and Wildlife Research 13.

Germano DJ, Pough FH, Morafka DJ, Smith EM and Demlong MJ. 2002. Growth of desert tortoises: implications for conservation and management. In Van Devender TR editor. The Sonoran Desert Tortoise: natural history, biology, and conservation. pp. 265-288. Tucson, Arizona: The University of Arizona Press.

Gibbons JW. 1986. Movement patterns among turtle populations: applicability to management of the desert tortoise. Herpetologica. 42(1): 104-113

Glenn JL, Straight RC, and Sites JW Jr. 1990. A plasma protein marker for population genetic studies of the desert tortoise (*Xerobates agassizi*). Great Basin Naturalist 50(1): 1-8.

Goldsmith A. 1990. Report on desert tortoise telemetry studies on Saguaro National Monument, 1989. Report to the National Park Service. 12pp.

Grandmaison DD. 2008. Desert Tortoise (*Gopherus agassizii*) Micro-habitat Selection on the Florence Military Reservation, Pinal County, Arizona. Abstracts 33rd Annual Desert Tortoise Council Meeting and Symposium. p. 13.

Grover MC and DeFalco LA. 1995. Desert tortoise (*Gopherus agassizi*): status-of-knowledge outline with references. General Technical Report INT-GTR-316, US Forest Service, Intermountain Research Station.

Hansen RM, Johnson MK and TR Van Devender. 1976. Foods of the desert tortoise, *Gopherus agassizii*, in Arizona and Utah. Hepetologica 32(3):247-251.

Harris Environmental Group. 2001. Integrated natural resources management plan and Environmental Assessment 2002-2006. Florence Military Reservation, Arizona Army National Guard, Pinal County, AZ.

Hart S, Woodman P, Bailey S, Boland S, Frank P, Goodlett G, Silverman D, Taylor D, Walker M and P Wood. 1992. Desert tortoise population studies at seven sites and a mortality survey at one site in the Sonoran desert, Arizona, 1991. Kiva Biological Consulting and EnviroPlus Consulting. Submitted to Arizona Game and Fish Department and Bureau of Land Management (Arizona State Office)

Henen BT. 1997. Seasonal and annual energy budget of female desert tortoise (*Gopherus agassizii*). Ecology 76: 283-296.

Henen BT, Peterson CC, Wallis IR, Berry KH and Nagy KA. 1998. Effects of climatic variation on field metabolism and water relations of desert tortoises. Oecologia. 117: 365-373.

Henen BT. 2002. Reproductive effort and reproductive nutrition of female desert tortoises: essential field methods. Integrative and Comparative Biology 42: 43-50

Homer BL, Li C, Berry KH, Denslow ND, Jacobson ER, Sawyer RH and Williams JE. 2001. Soluble scute proteins of healthy and ill desert tortoises (*Gopherus agassizii*). American Journal of Veterinary Research 62(1):104-110

Howland JM and Rorabaugh JC. 2002. Conservation and protection of the desert tortoise in Arizona. Fire ecology of the Sonoran Desert tortoise. In *The Sonoran Desert Tortoise: natural history, biology, and conservation*. Van Devender TR, editor. pp. 334-354. Tucson, Arizona: The University of Arizona Press.

Howland JM. 1994. Sonoran desert tortoise population monitoring. Nongame and Endangered Wildlife Program Technical Report 38. Arizona Game and Fish Department, Arizona.

Hulse AC and Middendorf GA. 1979. Notes on the occurrence of *Gopherus agassizii* (Testudinae) in extreme eastern Arizona. Southwestern Naturalist. 24(3): 545-546.

Jacobson ER, Gaskin JM, Brown MB, Harris RK, Gardiner CH, LaPointe JL, Adams HP and Reggiardo C. 1991. Chronic upper respiratory tract disease of free-ranging desert tortoises (*Xerobates agassizii*). Journal of Wildlife Diseases 27(2): 296-316.

Jacobson ER, Wronski TJ, Schumacher J, Reggiardo C, and Berry KH. 1994. Cutaneous dyskeratosis in free-ranging desert tortoises, *Gopherus agassizii*, in the Colorado Desert of southern California. Journal of Zoological Wildlife Medicine 25: 68-81.

Jennings WB 1997. Habitat use and food preferences of the desert tortoise, *Gopherus agassizii*, in the western Mojave Desert and impacts of off-road vehicles. *In* J. Van Abbema (ed.), Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles-An International Conference, pp. 42-45. New York Turtle and Tortoise Society, New York.

Jennings WB 1993. Foraging ecology of the desert tortoise (*Gopherus agassizii*) in the Western Mojave Desert, California. Proceedings of the 18th Symposium of the Desert Tortoise Council.

Johnson JD, and Averill-Murray RC. 2002. 2002 Health Surveys of Sonoran Desert Tortoises. [Desert Tortoise Council Symposium Abstract]

Jones CA, Schwalbe CR, Swann, DE, Prival DB, and Shaw WW. 2005. *Mycoplasma agassizii* in Desert Tortoises: Upper Respiratory Tract Disease in Captive and Freeranging Populations in Greater Tucson, Arizona. Final Report to the Arizona Game and Fish Department, Phoenix, AZ. Heritage Fund Urban Project No. U03005.

Kazmaier RT, Hellgren EC, Ruthven DC III, and DR Synatzke. 2001. Effects of grazing on the demography and growth of the Texas Tortoise. Conservation Biology 15(4):1091-1101.

Kristan WB and Boarman WI. 2003. Spatial pattern of risk of common raven predation on desert tortoises. Ecology 84: 2432–2443.

Kristan III WB, Boarman WI and Crayon J. 2004. Diet composition of Common Ravens across the urban-wildland interface of the west Mojave Desert. The Wildlife Society Bulletin. 32: 244-253.

Klug CM and Averill-Murray RC. 1999. Reproduction in Sonoran desert tortoises: a progress report. Proceedings of the Desert Tortoise Council Symposium. 1997: 59-62.

Lamb T, Avise JC and Gibbons JW. 1989. Phylogeographic patterns in mitochondrial DNA of the desert tortoise (Xerobates agassizii, and evolutionary relationships among the North American gopher tortoises. Evolution 43(1): 76-87.

Lamb T and McLuckie AN. 2002. Genetic differences among geographic races of the desert tortoise. In Van Devender TR editor. The Sonoran Desert Tortoise: Natural History, Biology, and Conservation. pp. 67-85. Tucson, Arizona: The University of Arizona Press.

Lawler H. 1986. The desert tortoise and its North American Relatives. Sonorensis (Arizona-Sonora Desert Museum Newsletter) 7(3): 6-15

Lewis-Winokur V and Winokur RM. 1995. Incubation temperature affects sexual differentiation, incubation time, and posthatching survival in desert tortoises (*Gopherus agassizi*). Canadian Journal of Zoology 73: 2091-2097.

Lowe CH. 1990. Are we killing the desert tortoise with love, science, and management? Pages 84–106 in Beaman KR, Caporaso F, McKeown S and M Graff, editors, Proceedings of the First International Symposium on Turtles and Tortoises: Conservation and Captive Husbandry, Chapman University, Orange, California, USA

Luckenbach, RA. 1982. Ecology and management of the desert tortoise (*Gopherus agassizii*) in California. In Bury RB editor. North American tortoises: conservation and ecology. pp. 1-38. US Department of the Interior, Fish and Wildlife Service. Research report 12.

Marlow RW and K Tollestrup. 1982. Mining and exploitation of natural mineral deposits by the desert tortoise, *Gopherus agassizii*. Animal Behavior 30(2):475-478

McArthur ED, Sanderson, SC, and BL Webb. 1994. Nutritive quality and mineral content of potential desert tortoise food plants. Research Paper INT-473. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 26 p.

McCord RD. 2002. Fossil history and evolution of desert tortoises (Genus Gopherus). In Van Devender TR editor. The Sonoran Desert Tortoise: natural history, biology, and conservation. pp. 51-66. Tucson, Arizona: The University of Arizona Press.

McLuckie AM, Schwalbe CR and T Lamb. 1996. Genetics, morphology, and ecology of the desert tortoise (*Gopherus agassizii*) in the Black Mountains, Mohave County, Arizona. Prepared for the Bureau of Land Management, Transwestern Pipeline Company, and the Arizona Game and Fish Department.

McLuckie AM, Lamb T, Schwalbe CR and RD McCord. 1999. Genetic and morphometric assessment of an unusual tortoise (*Gopherus agassizii*) population in the Black Mountains of Arizona. Journal of Herpetology 33(1):36-44

Minnich JE. 1977. Adaptive responses in the water and electrolyte budgets of native and captive desert tortoises, *Gopherus agassizii*, to chronic drought. Proceedings of the Desert Tortoise Council Symposium. 1977: 102-129.

Morrison PH and Smith IV HS. 2006. Distribution and abundance of native grasses in the mountains of the Sonoran Desert National Monument and adjoining portions of the Barry M. Goldwater Range, Pacific Biodiversity Institute, Winthrop, Washington. 52 pp.

Murphy RW, Berry KH, Edwards T, and McLuckie AM. 2007. A Genetic Assessment of the Recovery Units for the Mojave Population of the Desert Tortoise, Gopherus agassizii. Chelonian Conservation and Biology 6(2): 229–251.

Murray RC and Dickinson V. 1996. Management plan for the Sonoran Desert population of the desert tortoise in Arizona. Arizona Interagency Desert Tortoise Team.

Murray RC and Klug CM. 1996. Preliminary data analysis from three desert tortoise long-term monitoring plots in Arizona: sheltersite use and growth. Proceedings of the Desert Tortoise Council Symposium. 1996: 10-17.

Murray RC and Schwalbe CR. 1993. The Desert Tortoise on National Forest Lands in Arizona. Final Report submitted to USDA Coronado forest, Prescott National Forest, Tonto National Forest. 51 pp.

Murray RC, Schwalbe CR, Bailey SJ, Cuneo SP and Hart SD. 1996. Reproduction in a population of the desert tortoise, *Gopherus agassizii*, in the Sonoran Desert. Herpetological Natural History 4(1): 83-88.

Nabhan GP. 2002. When desert tortoises talk, Indians listen: traditional ecological knowledge of a Sonoran Desert Reptile. Fire ecology of the Sonoran Desert tortoise. In Van Devender TR editor. The Sonoran Desert Tortoise: natural history, biology, and conservation. pp. 355-376. Tucson, Arizona: The University of Arizona Press.

Nagy KA and Medica PA. 1986. Physiological ecology of desert tortoises in southern Nevada. Herpetologica 42(1): 73-92

National Park Service, Natural Resources Preservation Program. 1994. Protecting the threatened desert tortoise: a multi-park plan for primary survey, management and monitoring. Proposal. National Park Service, Natural Resources Preservation Program.

National Park Service, Western Region. Survey and monitoring of the desert tortoise (*Gopherus agassizii*) at Saguaro National Park. Cooperative agreement between National Park Service and the University of Arizona. Cooperative Agreement No. CA 8000-2-9001

National Park Service. 1999. Project proposal backfilling abandoned mining lands features for public and wildlife safety. Organ Pipe Cactus National Monument ORPI-I-250.

O'Conner MP, Zimmerman LC and Spotila JR. 2000. Effects of behavior, physiology and habitat on thermoregulation in desert tortoises. Abstract. American Zoologist 40(6):1155

Oftedal OT, Hillard S, and Morafka DJ. 2002. Selective spring foraging by juvenile desert tortoises (Gopherus agassizii) in the Mojave Desert: Evidence of an adaptive nutritional strategy. Chelonian Conservation and Biology 4: 341-352.

Oftedal OT. 2002. Nutritional ecology of the desert tortoise in the Mohave and Sonoran deserts. 2002. In Van Devender TR editor. The Sonoran Desert Tortoise: natural history, biology, and conservation. pp. 194-241. Tucson, Arizona: The University of Arizona Press.

Oldemeyer JL. 1994. Livestock grazing and the desert tortoise in the Mojave Desert. In Bury, RB and DJ Germano, editors. Biology of North American Tortoises. National Biological Survey, Fish and Wildlife Research 13.

Oliva JP, Horning JH and Matison J. 2004. Areas of Critical Environmental Concern: The Bureau of Land Management's Conservation Mandate. Unpublished report. Forest Guardians, Santa Fe, NM. 79pp.

Patterson, R. 1982. The distribution of the desert tortoise (*Gopherus agassizii*). In: R.B. Bury. (Ed) North American Tortoises: Conservation and Ecology. U.S. Dept. Int. Fish & Wildlife Serv. Wild. Res. Rep. (12): 39-49.

Peterson CC. 1994a. Different rates and causes of high mortality in two populations of the threatened desert tortoise *Gopherus agassizii.* Biological Conservation 70:101-108.

Peterson CC. 1996. Anhomeostasis: seasonal water and solute relations in two populations of the desert tortoise (Gopherus agassizi) during chronic drought. Physiological Zoology 69(6):1324-1358

Peterson CC. 1996. Ecological energetics of the desert tortoise (*Gopherus agassizii*): effects of rainfall and drought. Ecology 77(6):1831-1844

Pettan-Brewer KCB, Drew ML, Ramsay E, Mohr FC, and LJ Lowenstine. 1996. Herpesvirus particles associated with oral and respiratory lesions in a California Desert Tortoise. Journal of Wildlife Diseases 32(3):521-526

Pima County Arizona, Board of Supervisors. 1999. Determining vulnerable species within Pima County, Arizona. Discussion paper for the Sonoran Desert Conservation Plan. Pima County Board of Supervisors. Tucson, Arizona

Pima County Arizona, Board of Supervisors. 1999. Science and GIS update. Discussion paper for the Sonoran Desert Conservation Plan. Pima County Board of Supervisors. Tucson, Arizona

Pima County Arizona, Board of Supervisors. 2000. Draft Preliminary Sonoran Desert Conservation Plan. 84pp.

Pima County Arizona, Board of Supervisors. 2006. Draft Pima County Multispecies Conservation Plan. 224pp.

Propst L. 1997. Integrating Conservation and Development: A Case Study of the Rincon Institute. Effects of Urbanization in the Sonoran Desert.

Riedle JD and Averill-Murray RC. 2003. Disease incidence on Sonoran Desert long term monitoring plots. Pages 141-146 in Proceedings of the 2002 & 2003 Desert Tortoise Council Symposia.

Riedle JD, Averill-Murray R, Clayton C, Lutz L. and Bolen DK. 2008. Habitat Use by Desert Tortoises (*Gopherus agassizii*) on Alluvial Fans in the Sonoran Desert, South-Central Arizona. Copeia 2008, No. 2, 414–420.

Reyes OS and Bury RB. 1982. Ecology and status of the desert tortoise (*Gopherus agassizi*) on the Tiburon Island, Sonora. In: R.B. Bury. (Ed) North American Tortoises: Conservation and Ecology. U.S. Dept. Int. Fish & Wildlife Serv. Wild. Res. Rep. (12): 39-49 pp. (Ecología y estatus de la tortuga del desierto (*Gopherus agassizi*) en Isla Tiburón, Sonora).

Robichaux RH and Wirt EB. 1995. Survey and monitoring of the desert tortoise Gopherus agassizzi at Organ Pipe Cactus National Monument and Saguaro National Park. Proposal. Prepared for National Park Service, Natural Resources Preservation Program.

Robichaux RH and Wirt EB. 1996. Survey and monitoring of the desert tortoise (*Gopherus agassizii*) at Saguaro National Park. Annual report, phase one: survey transects 1995

Robichaux RH and Wirt EB. 1996. Survey and monitoring of the desert tortoise (*Gopherus agassizii*) at Saguaro National Park. Final Report to National Park Service, Saguaro National Park, Tucson, Arizona.

Robichaux RH and Wirt EB. 1996. Survey and monitoring of the desert tortoise (*Gopherus agassizii*) at Organ Pipe Cactus National Monument. Draft Annual Report: Phase one: survey transects, 1995, to National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona.

Robichaux RH and Wirt EB. 1998. Survey and monitoring of the desert tortoise (*Gopherus agassizii*) at Organ Pipe Cactus National Monument. Draft Annual Report: Phase two: monitoring plots 1996, to National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona.

Rostal DC, Wibbels T, Grumbles JS, Lance VA and Spotila JR. 2002. Chronology of sex determination in the desert tortoise (*Gopherus agassizii*). Chelonian Conservation and Biology 4(2): 313-318.

Schneider PB. 1981. A population analysis of the desert tortoise, *Gopherus agassizii*, in Arizona. Report to the BLM. Phoenix, Arizona. 44pp.

Schneider JS. 1996. The desert tortoise and early peoples of the western deserts. Special Report prepared for the Desert Tortoise Preserve Committee, inc.

Schumacher IM, Rostal DC, Yates RA, Brown DR, Jacobson ER and Klein PA. 1999. Persistence of maternal antibodies against *Mycoplasma agassizii* in desert tortoise hatchlings. American Journal of Veterinary Research 60(7): 826-831

Shields T, Hart S, Howland J, Johnson T, Ladehoff N, Kime K, Noel D, Palmer B, Roddy D and Staab C. 1990. Desert tortoise population studies at four plots in the Sonoran desert, Arizona. Nongame and Endangered Wildlife Program, Wildlife Management Division, Arizona Fish and Game Department, Phoenix, Arizona.

Spang EF, Lamb GW, Rowley F, Radtkey WH, Olendorff RR, Dahlem EA and Slone S. 1988. Desert tortoise habitat management on the public lands: a rangewide plan. US Bureau of Land Management, Division of Wildlife and Fisheries: Washington, DC.

Spotila JR, Zimmerman LC, Binckley CA, Grumbles JS, Rostal DC, List A Jr., Beyer EC, Phillips KM and Kemp SJ. 1994. Effects of incubation conditions on sex determination, hatching success, and growth of hatchling desert tortoises, *Gopherus agassizii*. Herpetological Monographs. 8: 103-116.

Stewart GR. 1991. Movements and survival of desert tortoises (*Xerobates* = *Gopherus agassizii*) following relocation from the LUZ solar electric generating station site at Kramer Junction, San Bernardino County, California. Unpublished report to LUZ Corp. Los Angeles. 94pp.

Tonto National Forest, US Forest Service. 1993. A conservation assessment for the desert tortoise (*Gopherus agassizii*). Draft. US Forest Service, Tonto National Forest

Tonto National Forest, US Forest Service. 1985. Tonto National Forest land management plan. US Forest Service, Southewestern Region, Denver, CO.

Torres CM and Andrade MV. 2005. Desert Tortoise (*Gopherus agassizii*) in Sonora, México. Abstracts of the 30th Annual Desert Tortoise Council Symposium, Tucson, Arizona. 21-22.

Tracy CR. 1996. Nutritional ecology of the desert tortoises: preliminary assessment of some impacts due to sheep grazing in the California Desert District. Report to National Biological Service. Univ. Nevada, Reno.

Turner RM and DE Brown. 1982. Sonoran desertscrub. In: Brown DE, ed. Biotic communities of the American Southwest--United States and Mexico. Desert Plants. 4(1-4): 181-221.

Turner RM. 1982. Mojave desertscrub. In: Brown DE, ed. Biotic communities of the American Southwest--United States and Mexico. Desert Plants. 4(1-4): 157-168.

United States Air Force. 2003a. Draft Environmental Impact Statement for the Barry M. Goldwater Range Integrated Natural Resources Management Plan. Vol. 1. Departments of the Air Force, Navy and Interior and Arizona Game and Fish Agency.

United States Air Force. 2003b. Draft Environmental Impact Statement for the Barry M. Goldwater Range Integrated Natural Resources Management Plan. Vol. 2. Departments of the Air Force, Nave and Interior and Arizona Game and Fish Agency.

United States Army. Yuma Proving Ground. 1997. Integrated Natural Resources Management Plan. Developed by Arizona Game and Fish Department, U.S. Fish and Wildlife Service, and U.S. Army Yuma Proving Ground. Yuma, Arizona.

US Fish and Wildlife Service. 1980. Endangered and threatened wildlife and plants; Listing as threatened with critical habitat for the Beaver Dam Slope population of the desert tortoise in Utah. 45 Fed. Reg. 55654.

US Fish and Wildlife Service. 1989. Endangered and threatened wildlife and plants; emergency determination of endangered status for the Mojave population of the desert tortoise. 54 Fed. Reg. 32,326 (Aug 4, 1989)

US Fish and Wildlife Service. 1990. Endangered and threatened wildlife and plants; determination of threatened status for the Mojave population of the desert tortoise. 55 Fed. Reg. 12178 (April 2, 1990)

US Fish and Wildlife Service. 1991. Endangered and threatened wildlife and plants; Finding on a petition to list the Sonoran desert tortoise as threatened or endangered. 56 Fed. Reg. 29453 (June 27, 1991)

US Fish and Wildlife Service. 1992. Biological opinion for the proposed Arizona Strip District Grazing program on Mojave desert tortoise habitat. US Fish and Wildlife Service, Ecological Services, Phoenix, Arizona.

US Fish and Wildlife Service. 1994a. Endangered and threatened wildlife and plants; determination of critical habitat for the Mojave population of the desert tortoise. 59 Fed. Reg. 5820 (Feb 8, 1994)

US Fish and Wildlife Service. 1994b. Desert tortoise (Mojave population) recovery plan. Report for US Fish and Wildlife Service, Portland, Oregon. 73 pages plus appendices.

US Fish and Wildlife Service. 1996. Policy regarding the recognition of distinct vertebrate population segments; notice. 61 Fed. Reg. 4772.

Van Devender TR, Lawler HE and Wirt EB. 1993. Preliminary study of desert tortoise (*Xerobates agassizii*) diet in the northeastern Sonoran Desert. Proceedings of the 18th Symposium of the Desert Tortoise Council.

Van Devender TR, Averill-Murray RC, Esque TC, Holm PA, Dickinson VM, Schwalbe CR, Wirt EB and SL Barrett. 2002. Grasses, mallows, desert vine and more: diet of the desert tortoise in Arizona and Sonora. In Van Devender TR editor. The Sonoran Desert

Tortoise: natural history, biology, and conservation. pp. 159-193. Tucson, Arizona: The University of Arizona Press.

Van Devender TR. 2002. Cenozoic Environments and the Evolution of the Gopher Tortoises (Genus Gopherus). In Van Devender TR editor. The Sonoran Desert Tortoise: natural history, biology, and conservation. pp. 29-51. Tucson, Arizona: The University of Arizona Press.

Van Devender TR. 2002. Natural history of the Sonoran Tortoise in Arizona: life in a rock pile. In Van Devender TR editor. The Sonoran Desert Tortoise: natural history, biology, and conservation. pp. 3-28. Tucson, Arizona: The University of Arizona Press.

Vaughan SL. 1984. Home range and habitat use of the desert tortoise (*Gopherus agassizzi*) in the Picacho Mountains, Pinal County, Arizona. M.S. Arizona State University, Tempe.

Vaughn ML, Garcia FR, Nabhan GP and West P. 2003. Desert Tortoise Mortality Surveys on Seri Lands Sonora, Mexico. Abstracts 28th Annual Meeting and Symposium of the Desert Tortoise Council, February 21-23, 2003. Available on-line at: http://www.deserttortoise.org/abstract/abstracts2003/2003abs65.html

von Seckendorff Hoff K and Marlow RW. 2002. Impacts of vehicle road traffic on desert tortoise populations with consideration of conservation of tortoise habitat in southern Nevada. Chelonian Conservation and Biology. 4(2): 449-456.

Walde AD, Harless, ML, Delaney DK and Pater LL. 2007. Anthropogenic Threat To The Desert Tortoise (*Gopherus agassizii*): Litter In The Mojave Desert. Western North American Naturalist. 67(1): 147–149.

Walker D and Avise JC. 1998. Principals of phylogeography as illustrated by freshwater and terrestrial turtles in the southeastern United States. Annual Review of Ecology and Systematics. 29: 23-58.

Walker M and Wood P. 2002. Standard wash tortoise inventory spring 2002. Submitted to Arizona Game and Fish Department, Nongame Branch by Peggy Wood Inc. Logan, UT.

Wallis IR, Henen BT and Nagy KA. 1999. Egg size and annual egg production by female desert tortoises (*Gopherus agassizii*): the importance of food abundance, body size, and date of egg shelling. Journal of Herpetology 33(3): 394-408

Weiss JL and Overpeck JT. 2005. Is the Sonoran Desert losing its cool? Global Change Biology 11: 2065-2077.

Wendland LD, Zacher LA, Klein PA, Brown DR, Demcovitz D, Littell R and Brown MB. 2007. Improved Enzyme-Linked Immunosorbent Assay To Reveal Mycoplasma agassizii Exposure: a Valuable Tool in the Management of Environmentally Sensitive Tortoise Populations. Clinical and Vaccine Immunology. 14(9): 1190-1195.

Wilson DS, Morafka DJ, Tracy CR and KA Nagy. 1999. Winter activity of juvenile desert tortoises (*Gopherus agassizii*) in the Mojave Desert. Journal of Herpetology 33(3):496-501

Wilson DS, Nagy KA, Tracy CR, Morafka DJ and RA Yates. 2001. Water balance in neonate and juvenile desert tortoises, *Gopherus agassizii*. Herpetological Monographs 15:158-170

Wimsatt J, Johnson J, Mangone BA, Tothill A, Childs JM and CA Peloquin. 1999. Clarithromycin pharmacokinetics in the desert tortoise (*Gopherus agassizii*). Journal of Zoo and Wildlife Medicine 30(1):36-43

Wirt EB. 1988. Two desert tortoise populations in Arizona. Unpubl. Report to the US BLM, Phoenix Arizona. 56pp.

Wirt E, Martin B, Hale S and Holm P. 1998. Results of three desert tortoise plots monitored in 1996 at Saguaro National Park, Tucson, Pima, Co. Arizona. Draft Copy.

Wirt E, Martin B, Hale S and Holm P. 1998. The 1996 Javelina and Burn desert tortoise monitoring plots conducted in Saguaro National Park, Tuscon, Pima, Co. Arizona. Draft Copy.

Wirt EB and Holm PA. 1997a. “Climatic effects on survival and reproduction of the desert tortoise (*Gopherus agassizii*) in the Maricopa Mountains, Arizona.” Report to Arizona Game and Fish Department.

Wirt EB and Holm PA. 1997b. Summertime climatic buffering provided by desert tortoise shelter sites in the Sand Tank Mountains, Barry Goldwater Air Force range, Maricopa Co., Arizona. Prepared for 56 CES/CEVN, Luke Air Force Base, Arizona.

Wirt EB, Holm PA and Robichaux RH. 1999. Survey and monitoring of the desert tortoise (*Gopherus agassizii*) at Organ Pipe Cactus National Monument. Final Report to National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona.

Wisdom MJ, Mills LS and Doak DF. 2000. Life stage simulation analysis: estimating vital-rate effects on population growth for conservation. Ecology 81(3):628-641

Wilson DS, Morafka DJ, Tracy CR and Nagy KA. 1999. Winter activity of juvenile desert tortoises (*Gopherus agassizii*) in the Mojave Desert. Journal of Herpetology. 33: 496-501.

Woodman P, Bernstein E, Frank P, Kent D, Pavliscak L and Smith J. 2001. Desert tortoise population surveys at five plots in Arizona, Fall, 2001. Kiva Biological Consulting Inyokern, CA. Submitted to Arizona Game and Fish Department, Nongame Branch.

Woodman P, Bernstein E, Furman C, Pavliscak L, Spake C, Smith J and Wright K. 2002. Desert tortoise surveys at five plots in Arizona, Fall, 2002. Kiva Biological Consulting Inyokern, CA. Submitted to Arizona Game and Fish Department, Nongame Branch.

Woodman P, Frank P, Keaton C, Reiley B and Smith J. 2003. Desert tortoise surveys at four plots in Arizona, Fall, 2003. Kiva Biological Consulting Inyokern, CA. Submitted to Arizona Game and Fish Department, Nongame Branch.

Woodman P and Shields T. 1988. Some aspects of the ecology of the desert tortoise in the Harcuvar study plot, Arizona. Prepared for the Bureau of Land Management, Phoenix Arizona. Contract # AZ950-CT8-10

Woodman P, Boland S, Frank P, Goodlett G, Hart S, Silverman D, Shields T and Wood P. 1993. Desert tortoise population studies at five sites in the Sonoran desert, Arizona, 1992. Kiva Biological Consulting and EnviroPlus Consulting. Submitted to Arizona Game and Fish Department and Bureau of Land Management (Arizona State Office)

Woodman P, Boland S, Frank P, Goodlett G, Hart S, Silverman D, Shields T and P Wood. 1993. Desert tortoise population surveys at five sites in the Sonoran desert, Arizona. Kiva Biological Consulting and EnviroPlus Consulting. Submitted to Arizona Game and Fish Department and Bureau of Land Management (Arizona State Office)

Woodman P, Frank P and Silva D. 1999. Desert tortoise population surveys at three sites in the Sonoran desert of Arizona, 1998. Kiva Biological Consulting Inyokern, CA. Submitted to Arizona Game and Fish Department, Nongame Branch.

Woodman P, Frank P and Silva D. 1999. Desert tortoise population surveys at three sites in the Sonoran desert, Arizona, 1998. Kiva Biological Consulting, Inyokern CA. Submitted to Nongame Branch, Arizona Game and Fish Department

Woodman P, Frank P and Silva D. 2000. Desert tortoise population survey at three plots in Arizona, fall, 2000. Kiva Biological Consulting, Inyokern CA. Submitted to Nongame Branch, Arizona Game and Fish Department

Woodman P, Frank P, Goodlett G and Walker M. 1997. Desert tortoise population surveys at two sites in the Sonoran desert of Arizona, 1996. Kiva Biological Consulting Inyokern, CA. Submitted to Arizona Game and Fish Department, Nongame Branch.

Woodman P, Frank P, Goolett G and Walker M. 1997. Desert tortoise population surveys at two sites in the Sonoran desert, Arizona, 1996. Kiva Biological Consulting, Inyokern CA. Submitted to Nongame Branch, Arizona Game and Fish Department

Woodman P, Frank P, Hart S, Goodlett G, Walker M, Roddy D and Bailey S. 1998. Desert tortoise population surveys at four sites in the Sonoran desert, Arizona, 1997. Kiva Biological Consulting, Inyokern CA. Submitted to Nongame Branch, Arizona Game and Fish Department

Woodman P, Hart S, Bailey S and Frank P. 1996. Desert tortoise population surveys at two sites in the Sonoran desert, Arizona, 1995. Kiva Biological Consulting, Inyokern CA. Submitted to Nongame Branch, Arizona Game and Fish Department

Woodman P, Hart S, Boland S, Frank P, Silverman D, Goodlett G, Gould P, Taylor D, Vaughn M and Wood P. 1994. Desert tortoise population surveys at five sites in the Sonoran desert, Arizona, 1993. Kiva Biological Consulting, Inyokern CA. Submitted to Arizona Game and Fish Department and Bureau of Land Management, Arizona State Office, Phoenix AZ.

Woodman P, Hart S, Frank P, Boland S, Goodlett G, Silverman D, Taylor D, Vaughn M and Walker M. 1995. Desert tortoise population surveys at five sites in the Sonoran desert, Arizona, 1994. Kiva Biological Consulting, Inyokern CA. Submitted to Arizona Game and Fish Department and Bureau of Land Management (Arizona State Office)

Woodman P, Silva D and Walker M. 2000. Desert tortoise population survey at the New Water Mountains, Arizona, 1999. Kiva Biological Consulting, Inyokern CA. Submitted to Arizona Game and Fish Department.

Yntema CL. 1968. A series of stages in the embryonic development of Chelydra serpentina. Journal of Morphology. 125: 219-252

APPENDICES

Petition to the U.S. Fish and Wildlife Service to List the Sonoran Desert Tortoise as an Endangered or Threatened Species Under the Endangered Species Act, 16 U.S.C. § 1531 *et seq*. (1973 as amended), and to Designate Critical Habitat.

Appendix 1. Identified Threats at 17 Permanent Study Plots

Appendix 1: Threats to the Sonoran Desert Tortoise Identified at Seventeen Permanent Study Plots

The table below tabulates data from permanent study plot reports summarizing potential threats to desert tortoises and desert tortoise habitat that were identified by biologists during surveys of the plots. The "score" is the index assigned by Boarman and Kristan (2008) in their status review (Appendix 3).

Plots Showing Statistically Significant Declines

East Bajada	Threat	Score	Comments
	Grazing	3	1,247 AUMs over 81,434 acres. Heavy recent use in some parts; dung sporadically throughout.
	Mining	1	Old evidence
	Roads/Vehicles	0	
	Hunting/Shooting	0	
	Urbanization	0	
	Dogs	1	Free-roaming dogs in 90s; dog-caused trauma in 2002.
	Burros	3	Greater recent usage than cattle. Compact burro paths throughout. Profuse quantities of dung.
	OHV	1	Light use
	Trash	2	Common along road, primarily beverage containers. Light scatter of old trash throughout.
	Fire	0	
	Recreation	1	
	Predators	0	
	URDT	1	
	CD	4	
	Additional Comments: Major die-off 1997-2002; 47 carcasses in 2002. 187 tortoise burrows trampled by cattle.		

Hualapai Foothills	Threat	Score	Comments
	Grazing	2	Cattle were not directly observed on the plot during the 2005 survey but tracks were seen on the plot once. Cattle droppings, none fresh, were throughout the plot except for on the steepest and rockiest slopes. Some areas, particularly in the washes and under the larger trees, were heavily impacted by cattle apparently seeking shade.
	Mining	0	No recent signs of mining

	Roads/Vehicles	2	An infrequently traveled jeep road extends east-northeast from Alamo road through the northwest portion of the plot; 3 instances of Off-Road-Vehicles passing along the jeep trail
	Hunting/Shooting	0	Old shotgun and rifle shells were scattered throughout the plot but none seemed to have been left recently.
	Urbanization	2	New developments in valley nearby
	Dogs	2	In 2001, 3 live tortoises appeared to have trauma resulting from domestic dog attacks and 4 carcasses had chew marks resembling gnawing associated with domestic dogs. Forty sets of domestic dog scat were seen on the plot. In 2005, one tortoise that had no trauma 4 years earlier had new trauma from a possible domestic dog attack but none of the 11 carcasses displayed gnaw marks. In 2005, no dogs or dog scat were observed on the plot.
	Burros	0	
	OHV	0	
	Trash	0	
	Fire	0	
	Recreation	0	
	Predators	1	2 deaths probably due to predation by mountain lion.
	URDT	3	
	CD	3	

Maricopa Mountains	Threat	Score	Comments
	Grazing	1	Within Big Horn allotment. In 2005, no cattle were seen on or in the vicinity and grazing on the plot seems to have been relatively light in 2005.
	Mining	0	
	Roads/Vehicles	1	Some vehicles on edge or slightly on plot.
	Hunting/Shooting	0	No hunting or shooting activity was observed on or in the vicinity of the plot during the 2005 survey.
	Urbanization	0	
	Dogs	0	
	Burros	0	
	OHV	1	Some tracks, 1 vehicle.
	Trash	0	
	Fire	0	
	Recreation	1	
	Predators	1	
	URDT	0	

	CD	3	

San Pedro Wash	Threat	Score	Comments
	Grazing	1	34 AUMs per section. Although cattle frequented lands near the plot, they were not observed on the plot itself. Old, dry droppings were found on much of the plot.
	Mining	1	Old evidence; copper smelter nearby causes air pollution, but closed now?
	Roads/Vehicles	3	Power-line (with access road) crosses most of the western half of the plot. Three other unpaved roads cross the northwest quarter of the plot. A fourth, Rhodes Ranch Road, a well-maintained route that provides access for a private ranch, crosses the extreme southeastern corner of the plot. When in the area, fieldworkers observed at least one vehicle every day, making it the most heavily used road on the plot. Some motorcycles and four-wheel-drive vehicles were observed on unpaved roads near the plot. In 2001 ranchers vehicles were observed on power-line roads and driving up LGJW. Access roads in general appear to receive little traffic.
	Hunting/Shooting	1	Spent shotgun shells are occasionally seen throughout the plot.
	Urbanization	0	
	Dogs	2	Domestic dogs, which were only heard in the distance this year. In 2001, fieldworkers were awakened several times by domestic dogs running through camp.
	Burros	0	
	OHV	0	
	Trash	3	Beverage containers, but these are rarely seen far from roads. Quantities of household garbage, yard debris, large appliances, a heap of clothing and another of worn-out tires were all distributed along two of the power-line access roads, west of the plot boundaries. Wind-borne garbage such as balloons and plastic shopping bags were seen throughout the plot.
	Fire	0	
	Recreation	1	
	Predators	3	Twelve tortoises (34% of the total encountered in 2004) had shell damage attributable to predator attacks. Wounds ranged from minor gnawing to extensively chewed shells.
	URDT	2	
	CD	1	
	Comments	Air pollution from smelter	

Plots Showing Marginally Significant Declines (p=0.01)

Harquahala Mtns	Threat	Score	Comments

	Grazing	2	10-year average was 1,502 AUMs. Cattle, mostly dung and trails, were observed on approximately half of the study plot, with burro sign more pervasive and widespread. No cattle were seen in 2004 than cattle sign.
	Mining	1	The mine sites and test pits are within 400 m of the plot's east boundary. The sites are currently inactive.
	Roads/Vehicles	1	Dirt road runs parallel to and about 100 m north of the plot boundary. It enters the plot in the northeast corner; No vehicles were seen on this road in 2004. A lightly used two-track dirt road splits off the north boundary road, enters the plot and ends in grid cell 02.
	Hunting/Shooting	2	Popular with quail and deer hunters. It is likely that most human visitation on the study plot area involves hunting.
	Urbanization	0	
	Dogs	0	
	Burros	2	Burro sign, mostly dung and trails, were observed on approximately half of the study plot. There is a wild burro population of approximately 28 animals that utilizes the Harquahala Mountains part of the time and has been slowly growing.
	OHV	0	No signs of other recreational activities were noted during the 2004 survey, and no vehicle tracks were seen off roads.
	Trash	2	Trash noted during the 2004 survey was mostly found around the regularly used camp site in Section 13, grid cell 02, and along the road leading to the camp. Away from the roads, most trash consisted of spent shotgun cartridges and occasional food and beverage containers.
	Fire	1	
	Recreation	0	No signs of other recreational activities were noted during the 2004 survey, and no vehicle tracks were seen off roads.
	Predators	2	Four tortoises appeared to have been depredated by mountain lions.
	URDT	2	
	CD	2	

Plots Showing None Significant Declines

Buck Mtn	Threat	Score	Comments
	Grazing	0	
	Mining	1	21 locations on the plot where mining assessment work has been conducted
	Roads/Vehicles	1	One dirt road bisect; Vehicles were observed on the road twice in 2005.
	Hunting/Shooting	0	Very little evidence of hunting.

	Urbanization	1	Several homes are within one mile.
	Dogs	0	
	Burros	0	
	OHV	0	
	Trash	1	Garbage was uncommon.
	Fire	0	
	Recreation	0	
	Predators	1	One tortoise was probably killed by a predator in 2002.
	URDT	0	
	CD	2	

Four Peaks	**Threat**	**Score**	**Comments**
	Grazing	1	History of cattle grazing.
	Mining	0	
	Roads/Vehicles	1	2 well used roads nearby.
	Hunting/Shooting	2	One gunshot death, some other evidence and active hunting nearby.
	Urbanization		
	Dogs	0	
	Burros	0	
	OHV	0	
	Trash	0	
	Fire	0	
	Recreation	0	
	Predators	2	6 mountain lion deaths, 2 trauma to live tortoises.
	URDT	1	
	CD	1	

New Water Mtns	**Threat**	**Score**	**Comments**
	Grazing	1	Prior cattle usage was evident on the plot; however, judging from the amount and color of dung present, usage was nonexistent or very light in 2003. No cattle were seen on or near the plot during the survey.
	Mining	1	There is no evidence that any of the claims were actively mined.
	Roads/Vehicles	1	Some of the roads are indistinct in washes but most are still passable. No vehicle tracks were seen on any of the roads.

	Hunting/Shooting	0	
	Urbanization		
	Dogs	0	
	Burros	0	
	OHV	1	Two ATVs passed by on the road north of the plot. Otherwise, no new tracks were seen on the roads on and around the plot.
	Trash	0	
	Fire	0	
	Recreation	0	
	Predators	1	In 2003, both carcasses were juveniles, estimated to have died within the past year. It appears they were killed by mammalian predators.
	URDT	3	
	CD	3	

West Silverbells	**Threat**	**Score**	**Comments**
	Grazing	2	Cattle were seen on the plot on a number of occasions, both north and south of the main ridge. Grazing on the hillsides is light and seems to be generally restricted to the lower slopes of the hills and the bajadas.
	Mining	1	Three locations on the plot where older mining was evident.
	Roads/Vehicles	0	No roads, new or old, were within the plot boundaries.
	Hunting/Shooting	1	Very little sign (shells, tracks or trash) of hunting was observed within the plot boundaries. A few casings, both from rifle and shotgun, were found on the plot, predominately in the canyon and on the slopes above the guzzler.
	Urbanization	0	
	Dogs	0	
	Burros	0	
	OHV	0	
	Trash	1	Garbage was uncommon.
	Fire		
	Recreation		
	Predators	1	One of the carcasses was probably depredated by a mountain lion
	URDT	1	
	CD	1	

Eagletail Mtns	Threat	Score	Comments
	Grazing	3	Used its full allotment of 2,100 AUM’s. There were 380 head grazed on the 179,000 acre allotment; Cattle usage on the Eagletail plot in the winter of 2003 was light, judging from the amount and color of dung present. Cattle have utilized all of the slopes used by desert tortoises, as evidenced by cattle dung.
	Mining	0	
	Roads/Vehicles	1	No vehicles in 2003. A few vehicles are seen at the camp during most surveys.
	Hunting/Shooting	1	Firearm casings, a few shotgun shells
	Urbanization	1	
	Dogs	0	
	Burros	0	
	OHV	0	
	Trash	1	Overall, litter on the plot was seen occasionally but was not of recent origin, with the exception of a few shotgun shells.
	Fire	0	
	Recreation	0	
	Predators	1	Three of the juvenile carcasses appeared to have been killed by a predator(s) and the other juvenile may have been killed in a fall or by a predator.
	URDT	2	
	CD	1	

Harcuvar Mtns	Threat	Score	Comments
	Grazing	2	Maximum of 211 animals year long; 2,532 AUM’s. No cattle observations occurred during the 2006 survey. Cattle sign (droppings and trails) were restricted to the ridges and low rolling areas in the southeast corner, as well as some of the benches on the more shallow sloped hillsides.
	Mining	1	Much evidence of old claims and mining activity.
	Roads/Vehicles	1	Very lightly used dirt road is the only road on the plot.
	Hunting/Shooting	1	Some nearby.
	Urbanization	0	
	Dogs	0	
	Burros	0	
	OHV	1	Two off-road vehicles were observed on the road that crosses the plot

	Trash	1	Beer bottles and cans present at the campsite. Other trash on the plot limited to a few balloons.
	Fire	1	
	Recreation	1	
	Predators	1	Two carcasses appeared to have been depredated a large predator.
	URDT	1	
	CD	2	

Bonanza Wash	Threat	Score	Comments
	Grazing	4	Cattle were seen many times in 1997 and 2006. Tracks and droppings were common throughout
	Mining	2	Affected by numerous mining ventures.
	Roads/Vehicles	1	Lightly-used roughly-bladed roads lie one-half mile west and south of the plot.
	Hunting/Shooting	0	
	Urbanization		
	Dogs	1	Seven carcasses found in 1992 were possibly the prey of a dog seen in the area. No other evidence of dogs has been seen since
	Burros	0	
	OHV	0	
	Trash	2	Old trash dump lies near
	Fire	0	
	Recreation	0	Highly accessible; only those affiliated with the study effort were seen on or near the plot
	Predators	0	
	URDT	1	
	CD	4	

Granite Hills	Threat	Score	Comments
	Grazing	2	No cattle were observed within plot boundaries during the survey. Evidence of past grazing (cattle dung) is throughout the plot, even in surprisingly rugged terrain.
	Mining	2	Majority of these impacts are mineral assessment scrapes, Some are overgrown and barely recognizable.
	Roads/Vehicles	1	A loop of roads associated with mining areas surrounds the Granite Hills plot.
	Hunting/Shooting	1	Most common forms of refuse were spent shotgun shells
	Urbanization	0	

	Dogs	0	
	Burros	0	
	OHV	2	The area seems to attract a small number of recreational vehicles, chiefly on weekends, but relatively few. On several occasions, light vehicles (probably jeeps) approached from the east and southeast, but did not actually drive onto the plot.
	Trash	2	Trash was common around areas of mining impacts. Old cans, wire and wood were the most common items. Outside of mining areas, the most common forms of refuse were spent shotgun shells and beverage (beer) cans and bottles, which were widely but sparsely distributed.
	Fire	0	
	Recreation	0	
	Predators	0	
	URDT	1	
	CD	2	

Tortilla Mtns	**Threat**	**Score**	**Comments**
	Grazing	3	200,000 acres and allows 1,080 AUM's. No cattle were grazed on the plot during the 2006 survey, although use in the past appears to have been heavy. Cattle dung and trails were on all but the steepest slopes and washes.
	Mining	2	21 locations on the plot where mining assessment work has been conducted
	Roads/Vehicles	3	17 vehicles seen or heard. Five roads with varying amounts of use are within the plot boundaries.
	Hunting/Shooting	0	Hunting appears to be minimal on the plot because very little evidence (shells, tracks, or trash) of hunting was observed.
	Urbanization		
	Dogs	0	
	Burros	0	
	OHV	2	Several vehicles in main wash.
	Trash	1	Garbage was uncommon.
	Fire	0	
	Recreation	0	
	Predators	1	6 carcasses killed by mountain lion in 90s.
	URDT	2	
	CD	1	

Arrastra	Threat	Score	Comments
	Grazing	4	1,674 AUM's over 34,967 acres. Several cows were seen at various times throughout much of the study north and south of the main road. Cattle and burro droppings, proliferating trails, and grazed vegetation were seen on all but a few very small inaccessible patches. Vegetation in several areas was heavily grazed including most of the perennial plants, especially on ridge tops and terraces.
	Mining	2	Numerous mining claim markers (wood stakes and rock cairns) spread throughout the plot, but there has been no recent activity
	Roads/Vehicles	3	3 to 4 vehicles were seen during weekdays – mostly in the early mornings or in the evenings. During the weekend up to 10 vehicles were seen using the road.
	Hunting/Shooting	0	No gunshots or hunters were seen.
	Urbanization	0	
	Dogs	0	
	Burros	3	Cattle and burro droppings, proliferating trails, and grazed vegetation were seen on all but a few very small inaccessible patches.
	OHV	0	
	Trash	1	Very little garbage.
	Fire	0	.
	Recreation	0	
	Predators	0	
	URDT	3	
	CD	3	

Little Shipp Wash	Threat	Score	Comments
	Grazing	4	Cattle were observed daily on the plot. 8 AUM's per section.
	Mining	0	
	Roads/Vehicles	3	A well-maintained dirt road, branching from the highway, borders the plot to the south and east. Several campsites (indicated by denuded areas, fire rings, and trash) were along the dirt road. A maintained spur runs through the northeast corner to the Kellis Ranch complex. An unmaintained spur extends west along the south edge of the plot, ending near the southwest corner at a historical camping area. One campsite was used during the survey, the usual site near the southwest corner.Vehicles were seen or heard on the maintained dirt road several times per week.

	Hunting/Shooting	3	Hunters, target shooters, and rock hounds made up the remainder of the traffic. Shooting was heard on and near the plot on several occasions, including late at night. Spent ammunition casings are scattered throughout the plot. Most of these were shotgun shells, fewer were rifle and pistol casings.
	Urbanization		
	Dogs	0	
	Burros	0	
	OHV	0	
	Trash	2	. There were also many cans and bottles scattered throughout the plot.
	Fire	0	
	Recreation	1	Hunters, target shooters, and rock hounds made up the remainder of the traffic.
	Predators	2	Two of the tortoises are believed to have been killed by mountain lion, two died of possible predation, and three died of unknown causes. Sixteen of the 41 carcasses collected on the Little Shipp Wash plot since 1990 are believed to be of tortoises killed by a mountain lion. Schneider (1980) also found tortoises killed by a mountain lion.
	URDT	1	
	CD	4	

Wickenburg Mtns	**Threat**	**Score**	**Comments**
	Grazing	4	The influence of cattle was evident over much of the plot. Observations of cows occurred daily as they traveled up and down the wash as part of their morning and afternoon movements
	Mining	2	Greatest mineral extraction was located 200 meters north; two denuded staging areas. Effort was made to divert water from a permanent puddle of water to one of the denuded areas. Digging tools had been left and black plastic pipe extended down the slope. Test pits, their spoils, and rock cairns marking claim corners were throughout the plot. M. Walker reported that mining efforts were abandoned in 1991, and there appears to have been no new activity since.
	Roads/Vehicles	1	Most are no longer passable and no vehicle tracks were seen on them.
	Hunting/Shooting	3	Hundreds of spent shotgun shells were scattered throughout the plot, and two accumulations of spent high caliber cartridges from target shooting were also observed.
	Urbanization	0	
	Dogs	0	
	Burros	3	Feral burros were observed once during the 2004 survey. In past years burros were seen daily.

	OHV	2	Off-Highway Vehicles (OHV) users were seen traveling up the wash every weekend. Once a week a ranch hand would travel up the wash to tend to the cows. A family was camped south of the plot on the last weekend of the survey.
	Trash	0	
	Fire	0	
	Recreation	0	
	Predators	0	
	URDT	0	
	CD	0	

Appendix 2. Summary Of Disease Reports In Sonoran Desert Tortoise Populations

Appendix 2: Summary of Disease Reports In Sonoran Desert Tortoise Populations

The table below tabulates data from both permanent study plot reports and other sites where tortoise health surveys have been performed.

Site	Year	Pop. Est (95% CI)	LIVE COUNT	CARCASS COUNT	CLINICAL SIGNS URTD	CLINICAL SIGNS CD	*Mycoplasma agassizii*	Source
Permanent Study Plots								
Arrastra Mts.	1997	23.9±6.10	14	2	7.1%	7.1%		Dickinson et al 2002, Woodman et al 2002
	2002	7±0	7	2	29%	0.0%		Woodman et al 2002, Riedel & Averill-Murray 2003
Bonanza Wash	1992		17	13	6%	41%		Woodman et al 2002, Dickinson et al 2002, Riedel & Averill-Murray 2003
	1997	27 (16-38)	13	2	8%	38%		Dickinson et al 2002, Riedel & Averill-Murray 2003
	2002	17 (8-26	13	2	23%	53%	0% (n=3)*	Woodman et al 2002, Riedel & Averill-Murray 2003
Buck Mtns.	2002	21±1.3	23				0%*	Riedel & Averill-Murray 2003
Eagletail Mts.	1992					0.0%		Dickinson et al 2002
	1993					2.7%		Dickinson et al 2002
	1994					8.5%		Dickinson et al 2002
Eastern Bajada	1990			5	18%			Dickinson et al 2002, Riedel & Averill-Murray 2003
	1993	67 (51-83)		10	4%	65.2%		Dickinson et al 2002, Riedel & Averill-Murray 2003
	1997	61 (50-72)		6	4%	62%		Dickinson et al 2002, Riedel & Averill-Murray 2003
	2002	9 (8-10)		67	33%	65%	0%*	Riedel & Averill-Murray 2003
Four Peaks	2001					37.5%		Woodman et al 2001
Granite Hills	1992					0.0%		Dickinson et al 2002
	1993					1.1%		Dickinson et al 2002
	1994					21.1%		Dickinson et al 2002
Harcuvar Mts.	1991						2 tortoises	Dickinson et al., 2002
	1993					15.2%		Dickinson et al., 2002
	1997					1.9%		Dickinson et al., 2002
	2002						0%*	Riedel and Averill Murray 2003
Harquahala Mts.	1988			4	0%	29%		Dickinson et al 2002, Riedel & Averill-Murray 2003
	1994	15 (13-17)		0	0%	63.2%		Dickinson et al 2002, Riedel & Averill-Murray 2003

	2001	10 (6-14)		3	12%	50%		Riedel & Averill-Murray 2003
Hualapai Foothills	1991			8	0%	9%		Riedel & Averill-Murray 2003
	1996	37 (34-40)		6	0%	12.8%		Dickinson et al 2002, Riedel & Averill-Murray 2003
	2001	16 (14-18)		11	0%	26%		Riedel & Averill-Murray 2003
Little Ship Wash	1992					15.9%	1 tortoise	Dickinson et al 2002
	1993					32.0%		Dickinson et al 2002
	1994					31.2%		Dickinson et al 2002
Maricopa Mts.	2005					19%		Woodman et al 2005
New Water Mts.	1999				0	3.8%		Woodman et al 2003
	2003				26.9%	23%		Woodman et al 2003
San Pedro Wash	1991			11	5%			Riedel & Averill-Murray 2003
	1995	125 (103-147)		9	6%	3%		Dickinson et al 2002, Riedel & Averill-Murray 2003
	2001	39 (22-50)		46	11%	0%		Riedel & Averill-Murray 2003
	2002						0%*	Riedel & Averill-Murray 2003
Tortilla Mts.	1992					5.8%		Dickinson et al 2002
	1996					9.7%		Dickinson et al 2002
West Silver Bell Mts.	1995					7.8%		Dickinson et al 2002
	2002						0%*	Riedel & Averill-Murray 2003
Saguaro National Park (SNP)								
Rincon Mts. Mother's Day Fire (n=25)	2002-2004					40.0%	48.0%	Jones et al 2005
Tucson Mts., Panther Peak Wash (n=19)	2002-2004					47.4%	52.6%	Jones et al 2005
Tucson Mts., Visitor Center (n=4)	2002-2004					25.0%	25.0%	Jones et al 2005
Tonto National Forest (TNF)								
Mazatzal Mts.	1992					3.9%		Dickinson et al 2002
	1995					34.9%		Dickinson et al 2002
Saguaro NP, Pima County	2002						21/25	Riedel & Averill-Murray 2003
Ragged Top Mountain, Pima County	2002						2/18	Riedel & Averill-Murray 2003
Sugarloaf Mountain, Maricopa County	2002						0/26	Riedel & Averill-Murray 2003
Military Bases								

Florence Military Reservation, Pinal County	2002						0/13	Riedel & Averill-Murray 2003
County and Private Lands								
Rincon Mountains, Rocking K Development n=18	2002-2004					50.0%	72.2%	Jones et al 2005
Rincon Mountains, Chiminea Creek n=8	2002-2004					0.0%	12.5%	Jones et al 2005
Tortolita Mountains, Saguaro Ranch Development n=4	2002-2004					0.0%	50.0%	Jones et al 2005
Tortolita Mountains, Derrio Canyon n=3	2002-2004					0.0%	0.0%	Jones et al 2005
Tumamoc Hill n=8	2002-2004					37.5%	75.0%	Jones et al 2005
Santa Catalina Mountains, Sabino Canyon Recreation Area n=9	2002-2004					11.1%	44.4%	Jones et al 2005
Ninetysix Hills n=13	2002-2004					0.0%	53.8%	Jones et al 2005
Black Mountain n=17	2002-2004					47.0%	58.8%	Jones et al 2005
Desert Peak n=1	2002-2004					0.0%	0.0%	Jones et al 2005
Sierrita Mountains, Stevens Canyon n= 9	2002-2004					44.4%	33.3%	Jones et al 2005

* Riedel & Averill-Murray 2003 tested 41 plasma samples from tortoises 6 study sites; the number of samples from each site is not indicated in the report but tested negative in the ELIZA.

Appendix 3. Status of Sonoran Desert Tortoise Populations in Arizona: 1987-2006 By William I. Boarman and William B. Kristan, III. October 1, 2008. 51 pp.

Status of Sonoran Desert Tortoise Populations in Arizona: 1987-2006

by

William I. Boarman
Conservation Science Research and Consulting
2522 Spring Valley, California 91977
conservation-science@cox.net

and

William B. Kristan, III
Department of Biological Sciences
California State University, San Marcos 92096
wkristan@csusm.edu

October 1, 2008

Abstract: While the desert tortoise (*Gopherus agassizii*) is federally listed as a threatened species in the Mojave Desert, it is not listed in the Sonoran Desert of Arizona. To determine if existing population data provide sufficient evidence to support a listing consideration of the Sonoran desert tortoise population under the Endangered Species Act (ESA), we analyzed animal mark-recapture data collected from 17 study plots located throughout the species range in Arizona. Annual tortoise population levels were then estimated using Lincoln-Petersen and Schnabel methods. Linear models were developed from these estimates to assess change in population size over time. We also compared abundance and population trends among study plots with a focus on differing levels of perceived threats, disease sign incidence, and prevailing habitat types.

The Sonoran population of the desert tortoise was found to have experienced statistically significant declines (3.52% annually from 1987 to 2006). This level of decline equates to an estimated 51% reduction in the number of adult and subadult tortoises on the subject study plots since 1987. At the level of individual study plots, statistically significant declines ranging from 5.87 to 14.88% per year were found on four study plots (East Bajada, Maricopa Mountains, Hualapai Foothills, and San Pedro Valley). No study plots were found to have experienced consistent, statistically significant increases.

Both upper respiratory tract disease (URTD), caused by *Mycoplasma agassizii*, and cutaneous dyskeratosis (CD), of unknown cause, were verified to occur on most Sonoran desert tortoise study plots. These two diseases have been implicated in drastic declines of desert tortoise populations in the Mojave Desert. Our analyses also indicate that some desert tortoise populations within the Sonora Desert may additionally suffer from

isolation and demographic stochastic events unique to small populations. We also identified threats from human activities that may affect Sonoran desert tortoise populations even though these populations often occur in steep, rocky habitats.

On the basis of this analysis, existing population data was found to provide sufficient evidence to support a listing reconsideration of the Sonoran desert tortoise population under the ESA.

Introduction

The desert tortoise (*Gopherus agassizii*) is listed as a threatened species in the Mojave Desert, but not in the Sonoran Desert of Arizona (USFWS 1991, 1994). A petition to list the Sonoran population of the desert tortoise was denied by the (USFWS 1991) because of: 1) a lack of evidence of significant tortoise declines in Arizona, 2) no indication that disease was affecting Arizona desert tortoise populations, 3) an assumption that a perceived higher level of isolation among subpopulations of Sonoran desert tortoises confers greater population stability, and 4) a presumption that the rocky habitat often used by Sonoran desert tortoises naturally protects them to a higher degree from human developments than similar threats to the species occurring within the Mojave population.

There was very little data available on Sonoran desert tortoise population status at the time of the 1990 Mojave population listing and subsequent USFWS (1991) listing petition determination. In 2008, considerable data are available from information collected on a roughly four-year cycle at 17 tortoise study plots located throughout the Sonoran tortoise's range in Arizona. Averill-Murray and Klug (2000) provided a thorough analysis of these data, including an evaluation of population trend, for the first 12 years (1987-1998) of data collection. They concluded that most tortoise populations in Arizona appeared stable, but that population trends were difficult to evaluate. They also found that future trajectories were particularly hard to predict given the rapid level of urbanization near several of the study plots. No evaluation of this previously analyzed data or any re-visitation of population threat assumptions has been completed since 2000, even though additional study plot and threat data have been collected.

Sonoran desert tortoise subpopulations in Arizona struggle against many human activities that pose threats to their persistence. Current domesticated cattle (*Bos taurus*) and wild burro (*Equus assinus*) grazing, as well as increasing levels of recreational activity (hunting, camping, off-road vehicle [ORV] use), and commercial mining are but a few of the human actions that pose threats to the persistence of tortoise populations. Both paved and unpaved roads pose a significant threat because vehicles crush tortoises. Roads also facilitate easy access to tortoise habitat by potentially hazardous human activities, and fragment populations into smaller, more vulnerable subpopulations.

Three additional threats to Sonoran tortoise subpopulations associated with human activities in select areas include impacts associated with urbanization, wildfire, and feral dog (*Canis domesticus*). There is little published literature examining the magnitude of this threat with regard to the desert tortoise sub-populations in Arizona.

With regard to tortoise disease threats, there is little published evidence that diseases have caused declines in tortoise subpopulations in Arizona (Dickinson et al, 2002). However, diseases are thought to be important factors affecting many Mojave tortoise populations and disease incidence has been detected at all study plots in the Mojave Desert (USFWS 1994, Berry 1997).

We analyzed the data collected from 1987 to 2006 from 17 study plots in Arizona to determine if there were any discernible trends in Sonoran desert tortoise populations in the state as a whole and at individual study plots. We compared tortoise abundance and population trends at these plots; levels of disease sign incidences, and prevailing habitat types were compared to ascertain if specific threats may be associated with observed desert tortoise population changes. Perceived threat categories were identified and study plots grouped accordingly to determine if there were similar trends among plots.

Methods

Survey Methods

We used data collected in a comparable manner on 17 study plots throughout tortoise habitat in Arizona (Table 1). The plots were established and are currently maintained by the Arizona Game and Fish Department and Bureau of Land Management. The locations of these study plots were designed to represent the geographic and habitat range of the Sonoran desert tortoise in Arizona, but they were not randomly selected. The characteristics of each study plot were described in Averill-Murray and Klug (2000) and Four Peaks study plot was described in Woodman et al. (2002).

Plots were visited an average of once every four years (range = 1 – 13 years). Data were collected by qualified individuals walking over each study plot two to five times each year in search of tortoises and their signs. Typically, study plots were surveyed for a total of 60 person days (8 hour days) over 45 calendar days, but there were many exceptions (Table 1). Until 2000, each plot was covered twice with the first coverage counting as the mark period in a mark-recapture study design and the second coverage counting as the recapture period (Woodman pers. comm.). Beginning in 2000, most plots

Table 1. Data were collected at 17 plots throughout desert tortoise habitat in Arizona. Individuals is the total number of individual tortoises seen on each plot during the survey during the year indicated. Columns marked Lower 95% and Upper 95% indicate the 95% confidence intervals for the population estimate, which was generated using the Schnabel method. Proportion of Unmarked Tortoises in Final Coverage represents the proportion of new tortoises seen on the survey that year during the last of two to five coverages of the plot.

				ADULTS					ADULTS AND SUBADULTS				
Plot	Year	Person Days	Number of Coverages	Individuals	Population estimate	Lower 95%	Upper 95%	Proportion of Unmarked Tortoises in Final Coverage	Individuals	Population estimate	Lower 95%	Upper 95%	Proportion of Unmarked Tortoises in Final Coverage
Arrastra	1987	60	2	13	18.3	6.27	88.90	0.73	15	24.0	8.21	116.38	0.75
	1997	35	2	13	15.0	6.89	40.87	0.40	13	15.0	6.89	40.87	0.40
	2002	35	2	6	6.0	2.34	22.02	0.00	7	7.0	2.73	25.69	0.00
	2006	18	3	7	21.0	3.77	829.46	0.50	8	27.0	4.85	1066.44	0.67
Bonanza	1992	60	2	13	14.7	6.74	39.97	0.25	14	16.0	7.35	43.60	0.25
	1997	35	2	10	10.5	4.82	28.61	0.25	10	10.5	4.82	28.61	0.25
	2002	35	4	10	11.0	5.05	29.97	0.50	11	12.0	5.82	29.85	0.43
	2006	18	3	11	13.1	6.38	32.69	0.63	12	14.9	7.21	36.95	0.63
Buck	2002	35	2	20	20.9	12.24	39.30	0.22	23	24.4	14.56	44.68	0.25
	2005	35	5	15	18.8	10.52	37.70	0.29	15	18.8	10.52	37.70	0.29
Eagletail	1987	60	2	34	39.1	24.05	68.34	0.36	34	39.1	24.05	68.34	0.36
	1990	60	2	27	31.2	17.84	60.32	0.29	29	34.5	19.75	66.77	0.33
	1991	36	2	28	33.3	19.08	64.51	0.40	29	33.9	19.84	63.71	0.38
	1992	35	2	23	25.9	14.48	51.90	0.27	23	25.9	14.48	51.90	0.27
	1993	35	2	23	28.4	14.98	62.21	0.44	23	28.4	14.98	62.21	0.44
	1994	35	2	27	30.7	17.56	59.35	0.48	28	32.6	18.65	63.06	0.48

	1998	35	2	30	30.4	19.87	49.08	0.28	31	31.4	20.56	50.77	0.30
	2003	35	2	26	26.8	16.98	45.28	0.25	26	26.8	16.98	45.28	0.25
Ebajada	1990	60	2	35	61.7	29.95	153.50	0.61	36	65.1	31.62	162.03	0.63
	1993	60	2	45	54.6	33.64	95.57	0.58	47	57.4	35.82	98.45	0.56
	1997	60	2	38	47.1	28.10	86.23	0.36	43	55.5	33.63	99.10	0.42
	2002	60	3	8	8.7	3.98	23.62	0.56	8	8.7	3.98	23.62	0.60
Four Peaks*	1992	56	2	41	80.0	38.83	198.98	0.65	44	90.0	43.68	223.85	0.67
	1995	56	2	43	53.6	33.02	93.82	0.52	46	59.8	36.83	104.64	0.52
	2001	60	2	37	48.0	28.07	90.15	0.55	40	53.5	31.31	100.55	0.59
Granite Hills	1990	60	2	27	49.5	19.33	181.67	0.56	31	62.5	24.41	229.39	0.60
	1991	60	2	40	47.1	29.39	80.78	0.32	49	57.6	37.66	93.00	0.32
	1992	60	2	35	39.4	24.25	68.89	0.47	45	52.5	33.99	85.95	0.43
	1993	60	2	42	53.7	32.58	96.01	0.42	55	78.8	48.49	137.77	0.54
	1994	60	2	49	55.0	36.96	85.84	0.27	61	67.6	47.35	100.19	0.23
	1998	60	2	31	40.1	22.41	80.31	0.52	36	46.2	26.99	86.68	0.50
	2003	60	3	36	39.4	27.26	59.28	0.25	51	57.1	41.60	80.70	0.28
Harcuvar	1988	65	2	51	57.4	38.88	88.70	0.29	55	63.8	43.25	98.65	0.34
	1993	60	2	40	45.5	29.12	75.53	0.44	44	50.0	32.71	80.77	0.43
	1997	60	2	49	54.0	36.85	82.67	0.33	50	55.5	37.88	84.96	0.33
	2002	60	3	41	42.9	29.89	64.10	0.44	42	43.4	30.59	63.90	0.43
	2006	40	4	45	45.5	34.78	60.73	0.17	46	46.9	35.89	62.67	0.17
Harquahala	1988	65	2	17	22.4	9.60	68.99	0.64	17	22.4	9.60	68.99	0.64
	1994	60	2	17	21.7	9.95	59.04	0.54	17	21.7	9.95	59.04	0.54
	2001	35	2	7	9.0	2.49	74.32	0.67	7	9.0	2.49	74.32	0.67
	2004	28	3	6	7.7	2.62	37.18	0.40	7	10.3	3.54	50.11	0.40
Hualapai	1991	60	2	32	41.8	23.37	83.77	0.45	32	41.8	23.37	83.77	0.45
	1996	60	2	36	39.7	25.41	65.91	0.27	37	40.5	26.22	66.30	0.26
	2001	60	4	15	18.2	10.66	34.24	0.14	15	18.2	10.66	34.24	0.14
	2005	35	5	11	9.8	6.35	16.04	0.25	11	9.8	6.35	16.04	0.25
Little Shipp	1990	60	2	64	73.8	48.76	117.79	0.23	67	79.1	52.24	126.20	0.26
	1991	60	2	66	81.4	55.54	124.59	0.43	68	83.6	57.43	126.79	0.43
	1992	60	2	69	80.6	56.11	120.33	0.29	79	97.1	67.61	144.99	0.34
	1993	60	2	74	79.9	59.10	110.84	0.33	83	91.0	68.01	124.76	0.33
	1994	60	2	59	75.4	49.34	121.85	0.42	62	81.0	53.02	130.93	0.43
	1998	60	2	45	53.6	33.51	92.09	0.41	48	58.5	37.02	98.71	0.44
	2003	60	3	55	64.4	46.93	91.03	0.22	58	69.4	50.54	98.03	0.22

Maricopa	1987	60	2	51	341.0	94.40	2815.75	0.91	52	245.3	83.95	1189.64	0.87
	1990	60	2	14	19.3	7.52	70.65	0.79	14	19.3	7.52	70.65	0.79
	2000	60	2	15	15.0	7.28	37.31	0.00	17	17.0	8.25	42.28	0.00
	2005	40	4	18	19.1	11.90	32.72	0.23	19	20.7	13.08	34.87	0.23
New Water	1988	50	2	13	13.0	7.07	27.11	0.00	15	15.0	8.16	31.28	0.00
	1999	35	2	16	17.1	9.01	37.42	0.36	17	18.7	9.83	40.82	0.36
	2003	25	2	20	23.1	12.17	50.54	0.31	23	27.0	14.68	56.30	0.33
San Pedro	1991	60	2	31	64.0	27.42	197.11	0.69	41	90.0	41.35	245.24	0.70
	1995	60	2	65	109.3	65.14	199.90	0.69	85	164.3	99.59	293.49	0.73
	2001	60	3	20	68.0	18.82	561.50	0.82	21	43.5	16.99	159.65	0.75
	2004	60	5	22	25.2	15.28	45.02	0.50	28	33.3	21.09	56.24	0.46
Tortilla	1992	60	2	45	58.9	35.73	105.30	0.56	49	63.1	39.42	108.35	0.54
	1996	60	2	59	75.8	49.56	122.39	0.48	60	76.0	50.20	121.27	0.46
	2001	60	2	47	66.0	39.34	120.72	0.58	48	68.4	40.74	125.03	0.58
	2006	40	4	58	88.0	59.61	135.98	0.44	68	111.3	75.38	171.95	0.53
West Silverbells	1991	60	2	51	75.4	44.96	137.97	0.56	59	95.1	56.71	174.03	0.62
	1995	60	2	69	88.2	59.75	136.29	0.49	75	97.8	66.78	149.79	0.51
	2000	60	2	92	130.4	89.60	197.83	0.53	101	147.9	102.30	222.51	0.55
	2004	60	5	90	103.0	80.96	133.18	0.37	97	112.9	88.90	145.67	0.41
Wickenburg	1991	60	3	15	18.4	8.94	45.84	0.67	15	18.4	8.94	45.84	0.67
	2000	35	2	13	13.2	7.18	27.53	0.17	15	15.6	8.48	32.53	0.17
	2004	35	5	18	18.3	12.89	26.92	0.13	18	18.3	12.89	26.92	0.13

* - Four Peaks may have consisted of 5 coverages in 1992 and 1995 (Averill-Murray pers. comm.), but this is not reflected in the data nor in Woodman et al. (2002). If this is correct, the results for those years at Four Peaks could be incorrect.

were covered three to five times, less thoroughly each time, but yielding more recaptures, which provides for a more precise population estimate. In the late 1990's plot sizes were reduced by eliminating areas lacking tortoise habitat and on which no tortoises had been found in previous surveys (Woodman pers. comm., Averill-Murray pers. comm.). The effect this reduction in size had on our analysis is likely minimal given that the same numbers of tortoises were probable located regardless of the size if the plot. On each survey, all tortoises are marked, sexed, and measured. Most plots were also reduced in size by eliminating areas not known to be used by tortoises; so, the entire area was less, but the number of tortoises likely remained more-or-less the same, assuming no changes in numbers caused by other factors (Woodman pers. comm.). General habitat, threat, and health characteristics were also recorded for plots. Between 2002 and 2006, 184 tortoises had blood drawn and enzyme-linked immunosorbant assay (ELISA) tests were conducted for antibodies to *Mycoplasma agassizii*, the organism causing URTD. More details and citations for annual reports from each plot can be found in Averill-Murray (2000) and Averill-Murray and Klug (2000). Surveys conducted since 2001 are reported in Woodman et al. 2002, 2003, 2004, 2005, 2006, and 2007. For our report, information on threats and disease prior to 2001 were obtained from these reports and summaries from previous years are contained within these latter reports.

Statistical Analyses

The data we used were designed to estimate population size via mark-recapture methods. Detectability can vary widely with weather, season, and habitat. Mark-recapture methods reduce this variability by using information about the fraction of tortoises in a sample that are marked to estimate population size. Because of this, sites with the same number of observed tortoises, but different probabilities of capture, will have different estimated population sizes. Plots were sampled between two and five times in any given year, and we used the Schnabel method to estimate population size for each year at each plot (Krebs 1989). The Schnabel method is like the Lincoln-Petersen method, in that population size is based on ratios of tortoises in a sample that are marked, and simplifies to the Lincoln-Petersen estimator when two surveys are used (the first as the marking interval, the second as the recapture interval), but it can accommodate more than two capture intervals. These population estimates were then used to assess population change over time. Estimates were made for only adults (i.e., all tortoises larger than 206 mm midline carapace length [MCL]) and adults and subadults combined (i.e. tortoises over 180 mm MCL), so that trends could be analyzed by size/age class. Smaller tortoises were not included because they are more difficult to survey and it was often impossible to estimate their numbers in a given year due to a lack of recaptures. Tortoises that were found dead were dropped from that year's estimate. The distribution of population estimates was skewed to the right so the data were log-transformed prior to analysis.

The analytical approach was to build linear models of increasing complexity to explain change in population size over time, and to test complex models against simpler ones with likelihood ration tests and by comparing R^2 values. The first, simplest model hypothesized a single rate of change over time, and a single overall population size for all plots. This first model was equivalent to a simple linear regression of log-population size over time, without accounting for differences in population size among plots or for different rates of change among plots. The next most complex model still used a single rate of change over time, but allowed for different overall population sizes among plots by allowing each plot to have a different intercept term. This model was equivalent to an analysis of covariance (ANCOVA), using year as a continuous covariate and plot as a categorical grouping variable. The most complex model allowed each plot to have a different rate of change, including the possibility that some plots could be stable or increasing while others were declining. This final model was also like an ANCOVA, but included a term for the interaction between year and plot.

To provide a more tangible measure of the estimated extent of change in population size, we used estimates of annual change in population size to calculate change over a 20-year period, equivalent to the span of time since the start of the standardized surveys. While more heuristic than using annual increases, this approach has two limitations. 1) It implies a linear change over the course of 20 years, which is clearly not always the case (e.g., Maricopa Mountains population; see below). 2) Surveys did not always span 20 years (e.g., Buck Mountains surveys spanned only three years and Four Peaks only nine); generally, nothing is known about the trajectory of each study population before its first mark-recapture survey. It should be reiterated that converting to 20-year trends was not the basis of our analyses, but only a method to provide some easy idea of how much a population experiencing a given mean annual change might change over a 20-year period. The 20-year value is most suspect for study plots that were studied over a very short time interval (e.g., Buck Mountains and Four Peaks).

To evaluate the plausibility that particular known threats contributed to tortoise declines, relative levels of known threats were categorized for each of the study plots (Table 2). Comparisons were first made between relative levels of each of the three most common threats: grazing, mining, and roads. Because threats are often found in combination, we also used Cluster Analysis to group interrelated threats to compare sites. We created two, three, and four clusters of threats to explore the effects of a range of groupings of threat types on tortoise populations. The best two-group classification separated sites that had few or no roads on or near them but had fire, from sites with many roads but no fire. The best three-group classification included a group with burros, a group with little or no grazing and no dogs or burros, and a group with high levels of road mortality. The best classification with four groups included a group with low overall disturbance, one with burros, one with high overall levels of disturbance (e.g., grazing, mining, roads, OHVs, etc.), and one with dogs. Each of these groupings were included in models that also included year, to see whether observed disturbance affected rates of change over time. A significant main effect for a threat or threat group would indicate that tortoise abundance at plots varies by threat level, but says nothing about trends. A significant interaction between threat level and year would indicate that rates of change over time depended on threats.

Table 2. Criteria used to categorize importance of each threat on each one of the 17 study plots.

THREAT	EVALUATION CRITERIA	RANGE
Grazing	Recency, frequency of cattle observed, AUMs, signs of grazing	0-4
Mining	Recency, claim markers, exploratory, evidence of mining	0-2
Roads/Vehicles	Number of roads traversing or near, how heavily traveled, frequency and number of vehicles seen on roads on or near plot	0-3
Hunting	Gunshot deaths, shotgun shells and firearm casings, presence of hunters	0-3
Urbanization	Number, recency, and nearness of residential developments	0-2
Dogs	Signs of dog attacks on tortoises, evidence of dogs on the plot, dogs at nearby residences	0-2
Burro	Frequency of burro observations, signs (tracks, trails, and scat)	0-3
OHV	Number and frequency of tracks, trails, and vehicles on or near plot	0-2
Garbage	Trash non-existent or rare to present in piles	0-2
Fire	Has or has not occurred on or near plot	0-1
URTD	Frequency and seriousness of signs, presence of positive ELISA tortoises	0-3
CD	Frequency and seriousness of signs	0-4

Habitat and disease may also affect tortoise abundance and population trends. Plots occurred in different habitat types, which could further have affected rates of change in tortoise populations. Habitat, or plant community, types were grouped as follows: 1) Nearly pure Sonoran Desert-Arizona Upland subunit, 2) mixed Arizona Upland/Lower

Colorado River subunits, 3) mixed Mojave and Sonoran Desert, and 4.) Sonoran Desert/Grassland/Interior Chaparral mix.

Signs of diseases implicated as possible contributors to tortoise population declines in other regions have been found on the study plots: an Upper Respiratory Tract Disease (URTD), possibly associated with *Mycoplasma agassizii*, *M. testudinum*, and/or other etiological agents; and a Cutaneous Dyskeratosis (CD), or shell disease of uncertain cause.

M. agassizii transmission involves direct contact with an infected tortoise (Brown et al. 2003), with tortoises believed to be contagious during periods of acute disease phases, where the infected tortoise exhibits clinical signs. Such signs include a mucous nasal discharge, wheezing, conjunctivitis, and lethargy. According to Schumacher et al. (1997), positive clinical signs statistically correlate with positive serology (i.e., exposure to *M. agassizii*). However, even though mucous nasal discharge has been found to be a fairly reliable predictor of positive serology, such a clinical sign can be caused by other pathogens. Positive serology (i.e., *M. agassizii* or *M. testudinum* antibodies detectable by an enzyme-linked immunosorbent assay, or "ELISA" test) indicates that a tortoise has been exposed to *M. agassizii* or *M. testudinum* (Schumacher et al. 1993). While positive serology does not necessarily indicate an active infection by *M. agassizii* or *M. testudinum*, it has been generally observed that seropositive tortoises are infected with *M. agassizii* or *M. testudinum*.

The effects of habitat and disease on rates of change were assessed using the same model structure as comparisons discussed above, with level of disease being relative categories.

Results

The mark-recapture results generated for adult and subadult tortoises together ($p = 0.05$; Table 3, 4) and for adult tortoises alone ($p = 0.004$) indicate that a decline in desert tortoise population size in Arizona has occurred and may be continuing. However, the model fit was not very strong ($R^2 = 0.038$ for adults and subadults and 0.098 for adults tortoises). Adding plot as a grouping variable, and thus allowing for differences in overall population size among plots, increased R^2 to 0.670 for adults and subadults, 0.645 for adults ($p < 0.0001$) (Table 3). Allowing year and plot to interact, such that each plot could have a different rate of population change, increased R^2 to 0.753 for adults and subadults and 0.734 for adults only ($p \leq 0.0001$ for both). Comparing these different models for each age group, using likelihood ratio tests, showed that allowing each plot to have a different overall population size caused a significant increase in model fit compared with a model that did not account for differences among plots, for both age/size class groupings (e.g., adults plus subadults, and adults only). Additionally, allowing for

Table 3. Results of ANOVA tests for effects of time and study site on population size at all 17 study sites.

ADULTS ONLY

Model 1: Only year included (no distinction among plots).

	Sum Sq	Df	F	P
year	4.837	1	8.9252	0.004
residuals	39.022	72		

adjusted R^2= 0.098

Model 2: Year and plot included (same slope, different intercepts)

	Sum Sq	Df	F	P
year	4.837	1	22.647	<<0.0001
plot	28.378	16	7.918	<<0.0001
residuals	11.961	56		

adjusted R^2 = 0.645

Model 3: Year, plot, and the interaction between them (each plot can have a different slope)

	Sum Sq	Df	F	P
year	4.837	1	30.329	<<0.0001
plot	27.061	16	10.604	<<0.0001
year x plot	5.582	16	2.187	0.023
residuals	6.380	40		

adjusted R^2 = 0.734

ADULTS AND SUBADULTS

Model 1: Only year included (no distinction among plots).

	Sum Sq	Df	F	P
year	4.680	1	8.423	0.049
residuals	71	40.007		

adjusted R^2 = 0.038

Model 2: Year and plot included (same slope, different intercepts)

	Sum Sq	Df	F	P
year	4.680	1	23.185	<<0.0001
plot	28.703	16	8.887	<<0.0001
residuals	11.304	55		

adjusted R^2 = 0. 670

Model 3: Year, plot, and the interaction between them (each plot can have a different slope)

	Sum Sq	Df	F	P
year	4.680	1	30.951	<<0.0001
plot	28.703	16	11.863	<<0.0001
year x plot	5.256	16	2.172	0.02377
residuals	6.048	39		

adjusted R^2 = 0. 753

different rates of change among plots significantly improved fit compared to a model that used a single rate of change for all three age/size class groupings. Although the tests indicate that plots have different slopes (Table 4), this result should be interpreted with caution because there were very few observations for several of the plots. Consequently, few of the rates of change are significant at the level of a single plot. It is best to use these final estimates as an indication that populations are not changing identically on all plots.

Table 4. Estimated population trends for each study population with t-test to determine if the slope differs significantly from zero.

Plot	n	ADULTS Slope	ADULTS Annual Trend (%)	ADULTS *t*	ADULTS *p*	ADULTS AND JUVENILES Slope	ADULTS AND JUVENILES Annual Trend (%)	ADULTS AND JUVENILES *t*	ADULTS AND JUVENILES *p*
All Plots (Model 1)	20	-0.045	-4.39	-2.988	0.0038	-0.044	-4.32	-2.902	0.00491
All Plots (Model 2)	20	-0.037	-3.64	-3.645	0.0006	-0.036	-3.52	-3.622	0.0006
Arrastra	4	-0.016	-1.59	-0.571	0.577	-0.017	-1.71	-0.632	0.537
Bonanza	4	-0.007	-0.70	-0.148	0.884	-0.003	-0.29	-0.064	0.950
Buck	2	-0.037	-3.60	-0.193	0.850	-0.090	-8.61	-0.486	0.634
Eagletail	8	-0.017	-1.66	-0.405	0.691	-0.018	-1.75	-0.439	0.667
Ebajada	4	-0.159	-14.66	-3.019	0.009	-0.161	-14.88	-3.150	0.007
Four Peaks	3	-0.051	-4.99	-0.756	0.461	-0.052	-5.08	-0.791	0.441
Granite Hills	7	-0.017	-1.70	-0.377	0.711	-0.013	-1.25	-0.284	0.780
Harcuvar	5	-0.012	-1.20	-0.303	0.766	-0.017	-1.72	-0.449	0.660
Harquahala	4	-0.075	-7.19	-1.748	0.101	-0.061	-5.87	-1.457	0.166
Hualapai	4	-0.108	-10.23	-2.287	0.037	-0.108	-10.27	-2.357	0.032
Little Shipp	7	-0.023	-2.31	-0.516	0.614	-0.025	-2.45	-0.561	0.583
Maricopa	4	-0.120	-11.33	-3.066	0.008	-0.101	-9.61	-2.644	0.018
New Water	3	0.036	3.65	0.780	0.447	0.035	3.58	0.787	0.443
San Pedro	4	-0.069	-6.65	-1.423	0.175	-0.099	-9.46	-2.109	0.052
Tortilla	4	0.022	2.25	0.470	0.645	0.034	3.42	0.731	0.476
West Silverbells	4	0.031	3.13	0.625	0.542	0.022	2.25	0.462	0.650
Wickenburg	3	-0.006	-0.62	-0.122	0.905	-0.003	-0.30	-0.061	0.952

The rate of change per year estimated for the first, simplest model was -4.32% for adults and subadults, and -4.39% for adults only (Table 4). The rate of change for the second model, with a common rate of change but different overall population sizes among plots, was -3.52% for adults and subadults, and -3.64% for adults alone (Table 4). When each plot was allowed to have a different slope, rates of change varied from – 14.88% to +3.58% for adults and subadults, and -14.66% to +3.65% for adults alone (Table 4). For both age class groupings, the steepest declines were at East Bajada (-14.88 and -14.66 per year, respectively; Figure 1), which are both statistically different from zero ($p < 0.01$). Maricopa Mountains had the second most negative trends (-9.61 and -11.33 per year), which were also statistically significant ($p = 0.008$ and $p = 0.018$; Figure 1). Adult and subadult and adult only trends were also significantly negative at Hualapai Foothills (-10.27%, $p=0.032$; -10.23, $p = 0.037$; respectively; Figure 1). At San Pedro Valley, only the adult plus subadults trend was very nearly significantly negative (-9.46%, $p=0.052$; Figure 1). Adults alone at San Pedro Valley exhibited a similarly steep negative slope (-6.65), but the results were not significant ($p = 0.175$). The fifth steepest negative declines, and only other ones anywhere near significant were at Harquahala Mountains (adults and subadults = -5.87, adults = -7.19; Figure 1), but these results were not significant. There were no significant increases at any of the sites. Results of these analyses for all individual plots are reported in (Tables 3 and 4, and Figures 2, 3 and 4).

We were concerned that the significant overall declines may have been unduly influenced by one of the plots, Maricopa Mountains, which consisted of large numbers of tortoises and several years of data, and showed a very abrupt decline; so we removed the Maricopa Mountains data and ran the analyses again. The declines for adults alone (-

1.14% per year) and adults and subadults combined (-0.92% per year) were smaller when Maricopa Mountains was removed, but remained statistically significant ($p \leq 0.05$) when differences in abundance among plots were accounted for. Therefore, we kept the Maricopa Mountains data in further analyses.

Although there were several threats that showed significant main effects, these indicate only that population size varies among levels of the threat, but do not indicate that rates of change over time are affected. Tests of differences in rates of change attributable to the threats come from interactions between the threats and year, and very few of the threats showed such an interaction. For adults, several threats showed significant main effects (roads and vehicles, hunting, burros, recreation, predators) but none had a significant interaction with year. A similar pattern was seen for adults and subadults combined, with several main effects (for roads and vehicles, hunting, burros, and recreation) but no interactions with year. Both types of disease (URTD and CD) had significant main effects for both adults with subadults (URTD: $F_{3, 66} = 6.280$, $p = 0.0008$; CD: $F_{4, 64} = 3.028$, $p = 0.023$) and adults alone (URTD: $F_{3, 66} = 5.634$, $p = 0.002$; CD: $F_{4, 64} = 3.094$, $p = 0.022$), but there was also a significant CD by year interaction for adults ($F_{4, 64} = 2.729$, $p = 0.037$); the interaction was nearly significant ($p= 0.066$) for adults combined with subadults. Including URTD and CD in the same model changed the numerical results for adults only (URTD: $F_{2, 66} = 18.382$, $p <<0.0001$; CD: $F_{2, 66} = 5.909$, $p = 0.004$), but did not change the interpretations. Habitat group also had significant main effects on tortoise numbers for both age class groupings (adults only: $F_{3, 67} = 4.711$, $p <<0.005$; adults plus subadults: $F_{3, 66} = 5.729$, p 0.002), suggesting different overall population sizes among habitats, but did not interact with year.

Possible clinical signs of URTD were found at 14 plots (all but, Buck Mountains, Maricopa Mountains, and Wickenburg Mountains) and of CD at 16 plots (all but Wickenburg Mountains). Between 2002 and 2006, blood was drawn from 184 tortoises and ELISAs run for *M. agassizii* and *M. testudinum*, the organism causing URTD, but only two (at Hualapai Foothills and Tortilla Mountains) were found to have been exposed and two (at Tortilla Mountains and Harcuvar Mountains) were suspect. An additional 51 were tested in 2007 and none tested positive for *M. agassizii*. Clinical signs of CD were particularly prevalent at four plots (71% on Harquahala Mountains in 1994, 61% on East Bajada in 2007, 53% on Bonanza Wash in 2002, 39% on Little Shipp Wash in 1994, and 38% on Four Peaks in 2001). Clinical signs of URTD were noted in multiple tortoises on 11 of the 17 plots: 0 to 9 tortoises have shown signs in any given year, with the highest numbers being on Eagletail Mountains (9 in 1990), New Water Mountains (7 in 2002), San Pedro Valley (6 in 2004), West Silverbell Mountains (4 in 2000), and Little Shipp Wash (4 in 1992).

The tortoise population sizes differed among habitat types, but rates of change were not different (i.e., the habitat main effect was significant, but there was no habitat by year interaction). Tortoise abundances were highest in solid Arizona Upland subdivision of Sonora Desert (AZSD) and AZSD combined with other Sonoran Desert habitat types (interior chaparral and grasslands), but lacking significant components of Lower Colorado subdivision or Mojave Desert vegetation types. The latter two vegetation types had half the number of tortoises of the others ($p = 0.006$).

Discussion

The monitoring protocol utilized at the tortoise study plots over 1987 to 2007 present challenges to rigorous statistical analysis of any collected data, particularly on a range-wide scale. Although this protocol was originally designed to model long-term population trends on the study plots, each survey is only a snapshot in time of a small section of a particular Arizona mountain range. Consequently, the small area intensively sampled may not adequately reflect the current status of tortoises throughout the breadth of the particular mountain range or adjacent lands. That the original plots are few and were not randomly selected exacerbates the problem.

However, they are the only data available to evaluate rangewide population trends in Arizona. By combining them, we made rangewide inferences using population estimates as an index of population size, which needs only to change in a predictable way when population size changes. Consequently, changes in the estimated population sizes over time across these plots should provide reliable information about population trends on the plots.

We based this analysis on estimated population sizes rather than on counts of tortoises seen at plots, even though the raw counts could be considered a population index. Although the confidence intervals around estimates can be relatively large, the fact that population estimates use information on the fraction of captured tortoises that are marked, in addition to the number captured, should make them a more reliable indicator of population size. For example, using the Schnabel method, we estimated approximately 245 adult and subadult tortoises to be present on the Maricopa Mountains plot in 1987, whereas 52 were found (Table 1). Because approximately four unmarked tortoises were captured for every marked tortoise that was recaptured, the 52 observed were clearly not nearly all the tortoises present. By the year 2000, nearly all of the adult or subadult tortoises captured were marked, such that the estimated population size was near or equal to the number captured in 2000 and 2005. Although the raw counts show a decline for Maricopa Mountains, the under-counting at large population size would have partially masked the magnitude of the decline. Similarly, plots with the same number of observed individuals (such as Arrastra in 2002) would be treated as though they have the same population size, even though differences in the marked fraction of their samples indicates that more tortoises are being missed in one of them. Because of this, we chose to use estimated population sizes rather than raw counts for our analysis of change in population size over time.

Apparently, survey protocols changed some after 2000. Before that, field workers spent more time selectively re-surveying areas where tortoises were previously found. Since this would likely increase the number of tortoise recaptured, it would likely reduce the estimated number of tortoises on the study plot (because there would be less difference between the numbered marked and the number recaptured). The result would likely be a bias in favor of an increase rather than a decrease over time. We could remove all collected before 2000, but this would greatly reduce the usefulness of the data. Since we cannot know for certain what effect the change in search protocols would have on the estimates, the conclusions reached are based on the best available information.

Combined Study Plots

There is strong statistically significant evidence of a 3.52% decline per year in the adult and subadult and 3.64% decline in the adult tortoise populations on the 17 study plots evaluated ($p < 0.005$). When the Maricopa Mountains plot, which exhibited precipitous declines of large numbers of tortoises compared to the others, was removed from the analysis, the overall decline was less (0.92% and 1.14%/year, respectively), but still significant ($p = 0.001$). The 3.52% annual decline represents an overall reduction of 51% in the adult and subadult populations represented by the 17 study plots over the 20 years that data were collected. Whereas the data were not sufficient to determine differences in trends among every plot, they were sufficient to establish this overall trend.

There are several alternative explanations for the decline in tortoise numbers that, if true, would not indicate an increased risk of population extinction. For example, it is possible that the surveyors' activities caused the declines on the plots, rendering the populations atypical of tortoise populations as a whole. This explanation is not consistent with the observation that the same trend is not observed in all plots, even though they have all been sampled using the same protocols. Secondly, tortoise populations may naturally experience cycles over several years or decades, and low numbers are an indication that populations are at a low point in the cycle, eventually to recover naturally. This alternative explanation does not question whether declines have occurred, but postulates that the current observed trend will naturally reverse without intervention. There are currently no data available to test this hypothesis. Additionally, regardless of the reason for decline, small population size puts populations at greater risk of extirpation from a variety of causes (demographic, genetic, or environmental). Given that it takes a long time for a population of a long-lived animal with a long juvenile period and delayed maturation to recover from low population size (Congdon et al. 1993), we believe it is more prudent to assume that the currently observed declines will continue, rather than to assume they will change in the future for reasons unknown. A third alternative is that the Sonora desert tortoise population in Arizona is fundamentally stable and that the available data are to flawed to test otherwise. This explanation is countered by data presented herein showing that overall, the statewide population is declining at a rate of over 3% annually and that at least four populations have experienced statistically significant declines over the past 20 years. Whereas the data used were imperfect, they do support the claim that the population of Sonora desert tortoises in Arizona is unstable. Conversely, on the basis of available data and reasonable statistical inferences, any conclusion that Sonoran desert tortoise subpopulations throughout Arizona are somehow secure is simply not supported by the information at hand.

Individual Study Plots Showing Significant Tortoise Population Declines

Tortoise mark-recapture data from the 17 study plots evaluated in this analysis exhibit so much variation among years, such low sample sizes, and few tortoises for most plots that estimates of trends for individual study plots were difficult to support. However, the results indicated that plots did not have identical rates of change, some were stable or possibly increased while others definitely or may have decreased, but most not significantly so. So that managers can have some idea of the possible status of individual populations, each plot is discussed in turn, even though many of the trends are not statistically significant.

Four plots had statistically significant declines: East Bajada, Maricopa Mountains, Hualapai, and San Pedro Valley (Figure 1). The Harquahala Mountains population may have experience a decline, the data had a negative slope, however the trend was not significant at the 0.05 level.

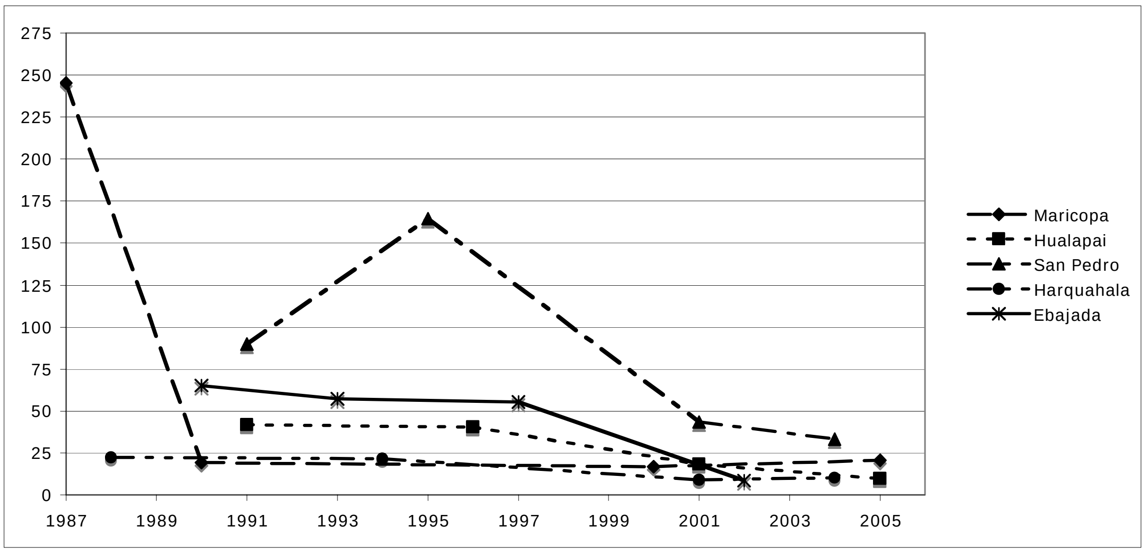

Figure 1. Population estimates for adult plus subadult tortoises on the four study plots that show statistically significant or nearly significant declines.

East Bajada.--The East Bajada population experienced the largest and most statistically significant declines of nearly 15% per year, which translates to almost 96% over 20 years. This population experienced a large die-off of adults between 1997 and 2002 with many dead and live tortoises showing signs of CD or some other shell disease. A large proportion (65%) of adults had sign of CD in 1997, before the crash. The numbers remained approximately stable in 2007and there was evidence of immigration, reproduction, and recruitment (Woodman et al. 2008). In addition to CD, its primary threats are rather heavy cattle grazing, burro activity, canine predation, and prolonged drought.

The East Bajada study plot tortoise subpopulation may be in a critical state and is particularly susceptible to the extirpation hazards of small populations.

Maricopa Mountains.--The Maricopa Mountains plot suffered statistically significant declines averaging 9.6% per year for adults and subadults. This represents an 87% decline since monitoring the population commenced in 1987. We note that differences among plots in the number of years surveyed, gaps of various time periods, and other inconsistencies made it necessary to use a model of change over time with a very simple, log-linear structure, and these projections of percent decrease over time are based on a constant proportional change in population size. This type of model may not be applicable to the Maricopa Mountains desert tortoise population, which experienced declines from unknown reasons during a major drought shortly after the first survey in 1987. The population experienced a major crash and appears to have since stabilized at a much lower level (approximately 10% of its former density). The Maricopa Mountains population estimate for 1987 was 245 (CI = 84 - 1190). The large confidence interval suggests that the actual population size in 1987 could have been as low as 84 tortoises. If this was the case, there still would have been a statistically significant decline of 76% between 1987 and 1990. A large percentage of dead tortoises may have had cutaneous dyskeratosis and/or bone/scute abnormalities (Pete Woodman, pers. comm.). The plot is within a wilderness area designated in 1992 and currently experiences very little human impacts. The population may be at greater risk of extinction from the demographic and genetic effects that occur in small populations, but otherwise its remoteness and lack of active impacts make it a good candidate for future recovery.

While the remoteness of this area and lack of ongoing human activities make it a good candidate for focused recovery efforts, the Maricopa Mountains study plot tortoise population may still be at great risk of extirpation due to the demographic and genetic vagaries associated with small populations.

Hualapai Foothills.--Adults and subadults combined experienced a 10.27% ($p = 0.032$) annual decrease (89% in 20 years) on the Hualapai Foothills plot. Adults alone also exhibited a significant decrease (10.23% annually, $p = 0.037$). The declines have been steady since 1990. This plot is in an area experiencing some urbanization and associated problems such as free-roaming dogs and evidence of URTD and a problem commonly associated with urbanization, i.e., free-roaming and feral dogs, has been noted within the study plot.

On the basis of noted impacts and an apparent increase of human activities in proximity to the study plot, extirpation of the associated Hualapai Mountains tortoise population is a distinct possibility in the near future.

San Pedro Valley.--The San Pedro Valley plot population experienced an average annual loss of 9.46% ($p = 0.052$, 86% in 20 years) among adults and subadults combined. There was an apparent increase between 1991 and 1995, but the 95% confidence intervals overlap so widely, the apparent population change more likely represents a sampling artifact rather than a demonstrable tortoise population increase. The losses were greatest between the 1995 and 2004 surveys with the estimated abundance dropping by 73% (164 to 44 adults and subadults), but there is some evidence that the losses may be abating as few dead tortoises and several unmarked females were found on or near the site during the 2004 survey (Woodman et al. 2005). Further, these impacts and associated human access may be increasing (Woodman et al. 2005). URTD may be present in this population, but the incidence of CD is quite low. Given low tortoise numbers, a high level of human impacts, and possible presence of disease, this population is decidedly at risk of extirpation in the near future.

Other Study Plots

None of the other trends for individual plots were statistically significant, however low sample sizes limited our statistical power at some plots. In the interest of maximizing our ability to detect likely trends and avoid the pitfalls of missing biologically significant declines, we will point out apparent trends even though they may lack statistical significance. This is important given that missing real declines could be disastrous for the given populations. We warn that these trends are only hypotheses that have very weak support and should not be taken as proof or strong evidence that the trends are real.

Harquahala Mountains.--The tortoise population on the Harquahala Mountains plot may have experienced declines (5.41% annually, 67% over 20 years for adults and 4.07% annually, 56% over 20 years for adults and subadults combined), but the trend was not significant. This population was quite small to begin with, which may explain the lack of statistical significance. The greatest reductions for adults plus subadults occurred between 2001 and 2004 surveys when the population may have suffered a 44% loss (from an estimated 18 to 10). There is little evidence that human-associated impacts are causing its decline (Woodman et al. 2006). The population is so small that it may be susceptible to the demographic risks associated with small populations, depending on its level of connection to other populations. Its survival likely depends on the nature and extent of the more extended population of which the sampled tortoises are a subset, and there is some evidence that the population may be denser (Woodman et al. 2005).

Mortalities on some plots (e.g., Maricopa Mountains) were probably episodic in nature, occurring as apparent mass mortality events over relatively short time periods. The episodic declines reflect the highly variable nature of desert environments. When evaluating population trend it is important to recognize that several years of stability may be followed by a single bad year (e.g., from drought) during which most mortality occurs. Other plots (e.g., East Bajada) exhibit what appear to be more steady annual declines. As discussed above, we cannot be certain whether these declines portend future extinction of the population or are part of a cyclic-type pattern of population fluctuations, but either way, the resulting low numbers increase the risk of local extinction caused by stochastic demographic events.

Of the remaining plots without significant results, two plots yielded negative trends that were sufficiently great they may portend problems for the populations' future viability: Buck Mountains and Four Peaks (Figure 2). These adult and adult plus subadult populations exhibited non-significant declines of 83 – 65% over the 20-year period. However, given that these trends are not significant, additional years of study would be needed to confirm that these declines are not merely sampling artifacts. The trends for Little Shipp Wash, Harcuvar Mountains, Granite Hills, Eagletail Mountains, and Arrastra Mountain populations were so close to zero, and p-values so high that they are likely stable or perhaps only slightly declining (Figure 3). New Water Mountains, Tortilla Mountains, West Silverbell Mountains, Wickenburg Mountains, and Bonanza Wash plots showed some increases, although they were not statistically significant (Figure 4).

Neither of the two plots yielding non-significant declines experienced large declines since they were first surveyed, but both should be watched closely (Figure 2). Both have smaller sample sizes than the others (Buck Mountains: 2 years; Four Peaks: 3 years) and more years are needed to better identify a trend.

Buck Mountains.--The Buck Mountains population of adults and subadults combined experienced an 83% decrease while adults alone exhibited a decrease of 52% over 20 years. However, these results should be viewed with great caution as they are based on only two surveys made three years apart (2002 and 2005) and come with widely overlapping confidence intervals (Table 1). We currently lack sufficient data to conclude much individually about some of the plots, particularly Buck Mountains and Four Peaks. However, large changes could go undetected with small sample sizes; for example, the Buck Mountains plot's estimated adult plus subadult decline of 8.61% (-3.60 for adults only) is based on only two data points separated by three years, and was not statistically significant. However, because percentage declines are multiplicative, this 8.61% decline would translate into an 83% decline (52% for adults alone) over a 20-year period, assuming a roughly linear decrease over that time period. Thus, even if declines are substantial, more data would be needed to establish whether plots like Four Peaks are in fact changing over time.

The population size at Buck Mountains is rather small (15-23), skewed strongly towards adults (i.e., very few subadult or smaller tortoises have been found), and five tortoises found in 2002 were found dead in 2005, which could be indicative of a disease sweeping through the population. No tortoises showed signs of CD and only mild signs of URTD were found. We found no information concerning the population's isolation or connectedness to surrounding tortoises. We will not know what the real population trend is for this population until more surveys have been conducted.

Figure 2. Population estimates for adult plus subadult tortoises on two study plots that experienced possible declines, but the trends were not statistically significant ($p = 0.634$ for Buck Mountains, and 0.441 for Four Peaks).

Four Peaks.--The data suggest the population at Four Peaks may have declined since 1987, but Woodman et al. (2002) believe it has remained stable. The three surveys conducted over a period of nine years (1992 - 2001) yielded a decline in adults and subadults of 5.08% per year, or 65% over 20 years ($p = 0.441$). There is inconsistency in information about the number of coverages each survey entailed: Averill-Murray (pers. comm.) contends there were five coverages, but the data and Woodman et al. (2002) say nothing on this. If there were five coverages, then the results could be slightly inaccurate. However, by assuming two coverages, we combined what would be the first three coverages into one, the "mark" period, and the last two into one, the "recapture" period. The result would likely be a slightly higher variance, but a similar mean population size for those years. Human impacts on the plot are quite low, but threats are high surrounding the plot. There are roads, busy Highway 87, hunting, and off-road activity nearby, which may isolate the population from other tortoises and could pose potential problems for the population. We found no information in the reports about the nature or extent of nearby tortoise populations that may help to stabilize this population.

Five plots show negative, but not significant, trends that are so small and weak that they may indeed be stable: Little Shipp Wash, Eagletail Mountains, Arrastra Mountains, Harcuvar Mountains, and Granite Hills (Figure 3).

Little Shipp Wash.--Little Shipp Wash plot may have experienced some declines since an apparent high point in 1993, but if the decline is real, it is relatively small (39% over 20 years among adults plus subadults) compared with East Bajada and Maricopa

Mountains plots. The confidence intervals are wide and broadly overlapping and the probability of not differing from zero trend is low (p = 0.537 – 0.780). There is some evidence of possible URTD and CD at Little Shipp Wash, and grazing and vehicle access are high. Mountain lion (*Felis concolor*) predation may be a concern there, but evidence of reproduction and little documented mortality suggest this population may be relatively healthy (Woodman et al. 2004). There is also good quality tortoise habitat nearby, so it is possible that this population is part of a much larger healthy one, and there is evidence of reproduction and recruitment.

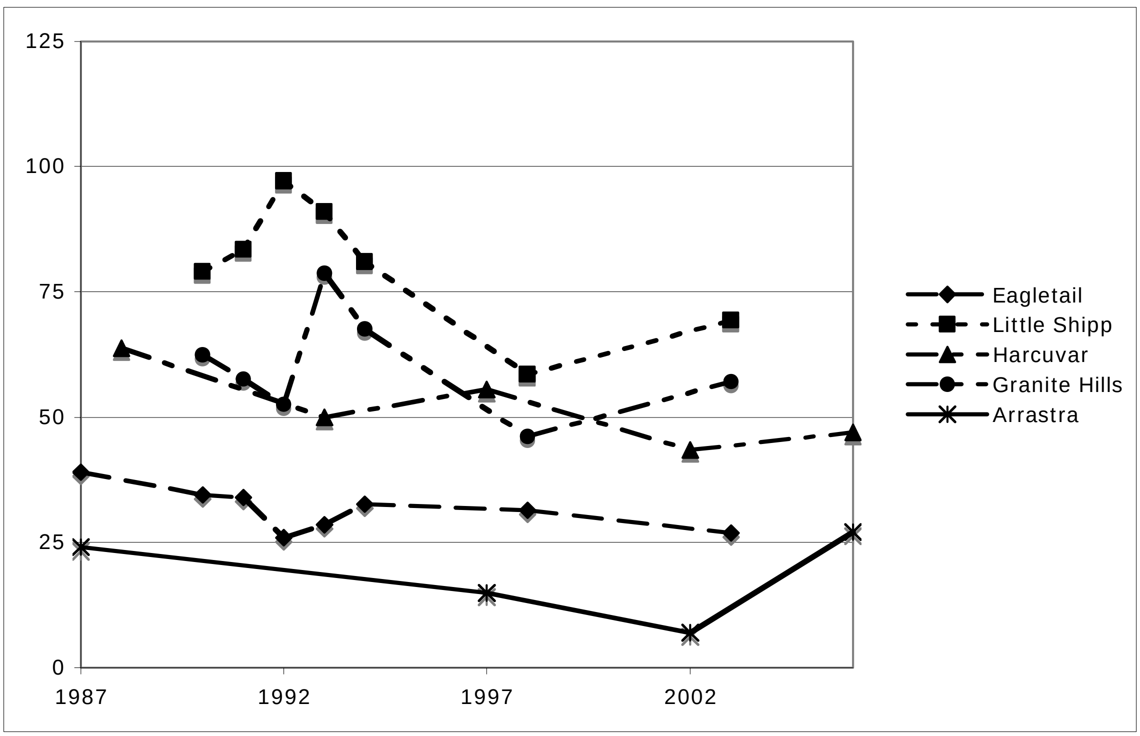

Figure 3. Population estimates for adult plus subadult tortoises on the five study plots that are probably close to stable or weakly declining (p = 0.537 – 0.780).

Eagletail Mountains.--The Eagletail Mountains population, with a non-significant 20-year trend of -30% ($p = 0.667$) for adults plus subadults, appears to be stable and warrants little concern, beyond the current periodic monitoring program. The greatest potential problems are active grazing and some evidence of CD, but these appear to have little effect on this population's stability.

Arrastra Mountain.--Arrastra Mountain results show an overall decline of 29% among adults plus subadults, but the numbers of tortoises are low and confidence intervals overlap considerably. Whereas there is little evidence of recent reproduction and recruitment, there is also little evidence of recent mortality. Grazing has been heavy on the plot, but its biggest problems are probably scarce habitat and small population size. The tortoise population may be stable, but should be watched closely due to the low number of tortoises that comprise this population.

Harcuvar Mountains.--The Harcuvar Mountains population is similarly important to watch closely, but may be relatively safe. The numbers of adults plus subadults may have declined by 29% ($p = 0.660$) over 20 years and the trend suggests a relatively steady, but mild decrease (Figure 3). One tortoise in 2006 was suspected of having been recently exposed to URTD, as determined by an ELISA. This combined with a relatively high level of documented mortality between 2002 and 2006 could be cause for alarm, which could be verified by the next survey.

Granite Hills.--The Granite Hills population has been fairly erratic, but of little concern. The adults plus subadults exhibited a non-significant decline of 22% over 20 years. There has been little documented mortality, some evidence of reproduction, and very little sign of diseases. The greatest concern comes from the low proportions of recaptures of marked tortoises between years and a probable isolation from other populations (Woodman et al. 2004).

On these latter five plots, the negative trends may be real, but the low statistical power, resulting from low sample sizes (number of surveys) and number of animals found, may have prevented us from obtaining statistically significant results in spite of the large estimates of annual declines. The level of annual losses (1.25% to 2.45%), if real, are not trivial and indicate that the populations should be watched and larger sample sizes obtained to determine if these are in fact trends.

The remaining five plots are either so close to zero, or have increasing trends, that they are of little concern relative to the other plots (Figure 4). Bonanza Wash was considered of great concern in 1992, but since then the evidence of high losses has abated, there is little evidence of disease or mortality, and some indication of immigration from outlying areas (Woodman et al. 2007). However, the existence of active heavy livestock grazing and moderately high human access coupled with very low tortoise abundance warrants possible concern for the population.

Wickenburg Mountains.--There has been little mortality on the Wickenburg Mountains plot and the population appears to be declining, but larger sample sizes may increase statistical power to detect a population change (Wickenburg Mountains only had three surveys) or increase confidence that the population is stable. There is considerable livestock grazing and small scaled, dispersed mining at Wickenburg Mountains. However, no disease signs detected and evidence of recent tortoise reproduction suggest that this population may be healthy and perhaps relatively stable. However, this plot has one of the lowest overall abundances of tortoises of all Arizona study plots analyzed, which makes it much more difficult to detect an apparent trend and increases its risk of extinction by random events.

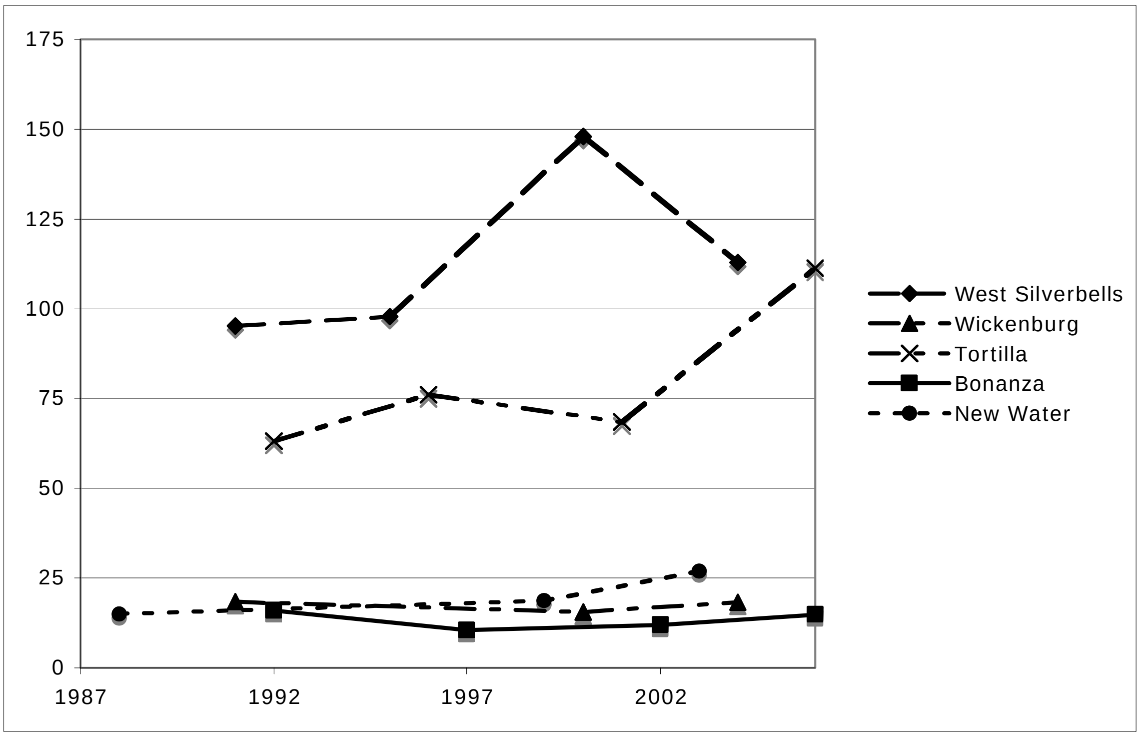

Figure 4. Population estimates for adult plus subadult tortoises on these five study plots that may be increasing or are stable (i.e., have slopes: -0.003 to +0.035, but very non-significant p values, 0.443 – 0.952).

West Silverbell Mountains.--The West Silverbell Mountains population has the highest number of tortoises of any plot, and estimates show a strongly positive slope. Adults plus subadult populations are estimated to have risen by 56% over 20 years and adults alone by 85%. However, estimates from 2004 are 24% lower than 2000, but not significantly different. Whether this represents the beginning of a downward trend, rather than sampling variation, can be re-evaluated after the next survey, scheduled for 2008. There is very little evidence of tortoise disease in the West Silverbell study plot population and anthropogenic threats are considered low. Both recent tortoise reproduction and recruitment have been documented. Consequently, there is evidence to suggest that the current population health is relatively secure.

Tortilla Mountains.--At Tortilla Mountains, the estimated tortoise population size has increased nearly consistently every year it was surveyed (with a slight dip in 2001, well within the standard error range): adults plus subadults may have exhibited a 96% increase over 20 years and adults 56%. There is evidence of reproduction and recruitment and abundance is high. However, in 2006, one tortoise tested positive for URTD, and another was suspect; this may be a concern if URTD is as deadly as some claim it has been in the Mojave Desert. Livestock grazing, dispersed mining and vehicle access are considered ongoing threats to the tortoise population in the area where this study plot is located, that could be acting as a significant stressor to an otherwise healthy tortoise population. Consequently, this tortoise subpopulation should be closely monitored.

New Water Mountains.--The New Water Mountains population estimates suggest a strongly increasing trend (102% over 20 years for adults plus subadults). The lack of statistical significance for this trend may be because there are only three surveys or because the total number of tortoises on the plot is quite low. There is a low level of anthropogenic threat and evidence of mortality is fairly inconsequential. Unfortunately, 27% of the population showed some signs that were consistent with URTD and 23% had some evidence of CD. Therefore, the stable or increasing numbers and low human impacts suggest low risk for the population, but the overall low numbers and high level of disease signs are both causes for alarm.

Threats to Tortoise Populations

We tested several major threats to determine if they help to explain the trends observed. However, the subjective ranking of the level of each threat that we used and the fact that the surveys were not designed to test for the effect of threats on the populations limited the accuracy of the analysis. For example, changes in tortoise numbers on plots exposed to threats compared with plots protected from threats would yield much stronger evidence of effects of threats on tortoise numbers, but the surveys were not designed in this way. We conducted the analysis of threats as an attempt to try to explain patterns of change over time using what was known about relative levels of threats to tortoises at the plots.

Cattle grazing, roads, garbage, and mining are the most prevalent threats on the plots. Nearly all of the results showed an effect of these and other individual threats on population size only, indicating that different average population sizes are associated with different levels of each threat (the “main effects” in the ANCOVA models). These associations do not indicate that different levels of the threat are associated with different rates of change in population size. For example, finding that different levels of road effects are associated with different tortoise population sizes, but that the level of road effects has no influence on rate of tortoise decline, is difficult to interpret. It is conceivable that the effects of roads occurred long ago, and that the differences in average represent new, lower, but now stable population sizes. Alternatively, it could be that roads have little effect on population growth on these plots, and that the differences seen are due to roads occurring in habitats with low value to tortoises. Finding an effect of threats on rates of change would be much stronger evidence of impact, and we hesitate to conclude that threats are impacting populations otherwise.

Evaluating the importance of the major anthropogenic threats singly yielded several significant effects of individual threats on adult and subadult tortoise abundance; however, the effects were associated with different overall tortoise population sizes among different levels of threats, but did not produce different rates of change over time. By grouping suites or clusters of perceived threats to tortoise populations, we reduced the complexities of dealing with several, potentially co-occurring threats to a few sets of relatively non-associated ones. With this approach, threat interpretation can be simplified, but it did not change the results of this analysis. The four-category grouping of threats was significant, but like the analysis of individual threats, did not produce different rates of change over time among threat groupings. Likewise, there was no association between habitat type and population trends.

Incidence of both disease types helped to explain population sizes, but had little effect on population trends. There was a nearly significant ($p=0.066$) effect of incidence of CD on population trends, but the real probability is even higher given the large number of comparisons made. However, it does weakly support the hypothesis that CD causes population declines. Possible clinical signs of URTD and CD were found at a majority of the plots (65% and 88%, respectively) and antibodies for *Mycoplasma agassizii*, the primary organism causing URTD, were found in two to four tortoises at two to three plots. Because our analysis primarily used clinical signs consistent with URTD, some of the apparent URTD infections could instead have been other, non-lethal health conditions. Additional study of the incidence of both diseases in these populations should be conducted so the contribution of disease to population change could be better assessed.

Management Implications and Recommendations

A petition to list the Sonoran population of the desert tortoise was previously denied by the USFWS for four reasons (USFWS 1991): insufficient evidence of declines, no indication that disease is affecting the population, the assumption that a higher level isolation among subpopulations confers greater stability, and the presumption that the rocky habitat used by Sonoran tortoises naturally protects the species more from threats associated with human developments and activities than does the habitat preferred by Mojave desert tortoises. The statistical analysis documented in this report directly addresses the first of these reasons and provides information contrary to the USFWS assertion that a possible listing of the Sonoran desert tortoise population is not warranted. In addition, our analysis uncovered information pertaining to the other three reasons stated for petition denial as well. On the basis of this information, several recommendations are made below:

1. <u>USFWS should revisit the basis for their previous decision not to list the Sonoran population of the desert tortoise given that more complete population data are now available.</u> Although the data available presented analytical challenges, it is the most

spatially extensive, longest duration data set available for addressing the status and trend of Sonoran populations of the desert tortoise. Significant declines of at least 3.5% per year between 1987 and 2007 have been documented at four of the 17 study plots, with an overall declining trend across the plots collectively. This equates to an estimated 51% reduction in the number of adults and subadults on study plots since 1987, when the surveys began. The data, although problematical, were sufficient to establish significant declines at four of the 17 study plots; they also establish the overall trend across the plots collectively. We believe that both the availability of data and the conclusions drawn from those data warrant a re-evaluation by U.S. Fish and Wildlife Service of its 1991 decision to not list the Sonoran population of the desert tortoise.

There is also evidence of disease in most of the study populations; several of which are so small and isolated that they are at risk of extirpation due to the demographic and genetic vagaries associated with small populations. Threats have also been documented at almost all of the evaluated study plots despite the use of rocky habitat by tortoises in some instances. Thus, the conclusions drawn from these data certainly warrant a re-evaluation of the USFWS (1991) premise that there is no evidence of tortoise declines; no disease in the Sonoran population of the desert tortoise; that the relative isolation of these subpopulations confers a high rate of population stability; and that the rocky habitat commonly used naturally protects the species.

2. <u>Continue regularly scheduled surveys of established study plots.</u> In analyzing data collected at four study plots (namely, East Bajada, Maricopa Mountains, San Pedro Wash, and Hualapai Foothills), statistically significant tortoise population declines were identified. Non-significant, but large estimated declines were found at eight additional

study plots (namely, Harquahala Mountains, Buck Mountains, Four Peaks, Little Shipp Wash, Eagletail Mountains, Arrastra Mountain, Harcuvar Mountains, and Granite Hills). The low number of surveys conducted may have caused the lack of statistical significance in many of the latter plots. Continued surveys will help to refine interpretations presented herein and could serve to test hypotheses proposed herein for individual plots. More surveys will also help to clarify if observed declines represent episodic, cyclic, or catastrophic crashes.

3. Monitor plots for signs of disease. There are two diseases that have been verified in Sonoran tortoises, both of which are suspected causes of considerable mortality in Mojave desert tortoises. Clinical signs of URTD, a respiratory disease associated with *M. agassizii* and/or *M. testudinum*, have been noted in multiple tortoises on 82% of the plots (all but, Buck Mountains, Maricopa Mountains, and Wickenburg Mountains). Signs of CD, a disease of the shell, have been found on 16 study plots (all but Wickenburg Mountains), and in an in a consistently and alarmingly high proportion of tortoises (>20%) on five (namely, Bonanza Wash, East Bajada, Harquahala Mountains, Little Shipp Wash, and Four Peaks). Data collected during continued monitoring of these populations could be used to determine trends in disease proliferation. Such data could also be used in ongoing and future research on desert tortoise disease epidemiology.

4. Determine level of demographic and genetic connectedness of study populations to other nearby populations if they exist. Whereas population isolation may provide a degree of protection relative to the introduction of infectious pathogens, isolation also has costs. Where there is little or no connection between populations, i.e., a

metapopulation structure, the risk of local extirpation due to the demographic and genetic vagaries associated with small populations, or even local environmental condition deterioration, is high. The viability of metapopulation units is always dependent on immigration among individual segments of the larger population; or if not periodic immigration, stable to increasing reproduction. Historically, separate desert tortoise populations in the Sonora Desert probably had higher levels of interaction than exist today (Edwards et al. 2004). The individual segments of a metapopulation are each subject to independent extinction, especially if they are small in size for whatever reason (e.g. habitat loss, drought, roads). Viability of metapopulations is dependent on immigration among individual segments of the larger population.

Several populations evaluated in this analysis are currently comprised of a very low numbers of tortoises (e.g., Arrastra Mountains, Bonanza Wash, Harquahala Mountains, Hualapai Foothills, Maricopa Mountains, and Wickenburg Mountains). Some of these metapopulation segments may be currently experiencing the inherent of small population size. For example, the Arrastra Mountains population, with less than an estimated 20 tortoises, has suffered possible declines, but from no known cause. There is little evidence of reproduction or recruitment into the reproductive size/age class, which may be caused by the Allee Effect – the difficulty of finding acceptable mates when a population is sparsely distributed. The Harquahala Mountains plot also has very low numbers (estimated 10 in 2004), little evidence of reproduction, and the sex ratio is highly skewed towards males (6:1). Without sufficient connectedness to other populations, these two populations may go extinct simply due to demographic stochasticity. There is some hope for the Harquahala Mountains population: nearby transects conducted in 2004 indicated that tortoise population densities may be higher in the surrounding area (Woodman et al. 2005). Little data exist for most study populations to evaluate the level of connectedness between tortoises on plots and other individuals of metapopulations. Such an analysis would be important for the effective management of the Sonoran population of desert tortoises in Arizona. A better understanding of the genetic and demographic connections between the study plots and the surrounding populations or metapopulations will be invaluable to proper management of the populations. We urge that such a study be undertaken sooner rather than later.

5. Further evaluate associations between tortoise habitat type and fragmentation potentials, as well as tortoise population threats, resulting impacts , and long-term viability of Arizona tortoise populations. The steep rocky habitat frequented by tortoises in the Sonoran desert may protect them to a higher degree from human developments more than in the Mojave Desert. However, threats to tortoises in this type of habitat have nonetheless been documented to occur; and in some instances, appear to be increasing in severity or extent. Any resulting impacts from these threats can result in habitat deterioration in a fairly rapid manner, with catastrophic consequences in the circumstance of a small subpopulation. Further, habitat deterioration may increase the susceptibility or severity of several types of identified tortoise population threats, with potential ramifications on population recruitment associated with both reproduction and/or immigration.

6. Integrate and synthesize existing data on desert tortoise populations and management options from established study plots and all sources of information associated with Sonoran Desert tortoise habitat parameters, threats and current weather

patterns. Many questions important to the effective conservation and management of the desert tortoise are currently unanswered. How much movement is there between populations and how much is needed to sustain population persistence? What degree of actual impact is associated with identified threats to tortoise populations? How much reproduction and recruitment is occurring and is there a geospatial, temporal, or other discernable pattern? At what point does habitat degradation become detrimental to population recruitment associated with reproduction and immigration? Are there associations between impacts resulting from existing threats, disease, changing weather patterns, and tortoise demography?

An enormous amount of data on various parameters has been collected on the 17 study plots. Other information relative to optimum tortoise habitat parameters, disease epidemiology, current and projected weather patterns, as well as the range of options for improved management within Sonoran desert tortoise populations, exists. If thoroughly analyzed and synthesized, these data might provide an effective direction to ensure long-term population viability within the Sonoran Desert.

7. Removing or reducing the severity and extent of impacts resulting from identified tortoise population threats may help to reverse tortoise population declines. Cattle and wild burro grazing, vehicle thoroughfare travel, mining, and recreational vehicle use, access are the most prevalent threats producing varying levels of impact to tortoise populations throughout Arizona. Removing or reducing the severity of impacts associated with these threats will help to improve the likelihood of survival of the Sonoran population of the desert tortoise. These threats and resultant impacts to tortoise populations are complex, interactive, and synergistic; reducing one or two primary threats

may help, but removing one high-level threat may not achieve the intended results because other threats thought to be less important may increase in importance as a result (e.g., reducing the chances of being crushed on roads may increase the number of tortoises now vulnerable to impacts from livestock grazing).

Acknowledgments

Pete Woodman provided access to the 20 years of data and clarification of many aspects of those data. He also helped with the interpretation of the trends and provided comments on an earlier version of this paper. Roy Averill-Murray, Tom Egan, Cristina Jones, Daren Riedle, and Phil Rosen provided useful comments on an earlier draft of this report. Cristina Jones and Tom Jones helped provide legal access to the data. Nicole Rosmarino (WildEarth Guardians, formerly known as Forest Guardians) and Tom Egan (Desert Tortoise Council) were instrumental in getting the project started and WildEarth Guardians and their members provided funding. We owe our indebtedness to all of these individuals and entities.

Literature Cited

Averill-Murray, R. C. 2000. Survey protocol for Sonoran desert tortoise monitoring plots: Reviewed and revised. Arizona Interagency Desert Tortoise Team.

Averill-Murray, R. C. and C. M. Klug. 2000. Monitoring and ecology of Sonoran desert tortoises in Arizona. Nongame and Endangered Wildlife Program Technical Report 161. - Arizona Game and Fish Department, Arizona.

Berry, K. H. 1997. Demographic consequences of disease in two desert tortoise populations in California, USA. Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles - An International Conference, pp. 91-99.

Brown, D. R., I. M. Schumacher, G. S. McLaughlin, L. D. Wendland, M. B. Brown, P. A. Klein, and E. R. Jacobson. 2003. Application of diagnostic tests for mycoplasmal infections of desert and gopher tortoises with management recommendations. Chelonian Conservation Biology 4(2):497-507.

Congdon, J. D., A. E. Dunham, R.C. Van Loben Sels. 1993. Delayed sexual maturity and demographics of Blanding's turtles (Emydoidea blandingii): Implications for conservation and management of long-lived organisms. Conservation Biology 7(4): 826-833.

Dickinson, V. M., J. L. Jarchow, M. H. Trueblood, J. C. deVos. 2002. Are free-ranging desert tortoises healthy? Pp. 242-262 *in* The Sonora desert tortoise: natural history, biology, and conservation, ed. By T. R. Van Devender. University of Arizona Press, Tucson.

Edwards, T., C. R. Schwalbe, D. E. Swann, and C. S. Goldberg. 2004. Implication of anthropogenic landscape change on inter-population movements of the desert tortoise (*Gopherus agassizii*). Conservation Genetics 5:485-499.

Howland, J. M. and J. C. Rorabaugh. 2002. Conservation and protection of the desert tortoise. Pp. 334-354 *in* The Sonora desert tortoise: natural history, biology, and conservation, ed. By T. R. Van Devender. University of Arizona Press, Tucson.

Krebs, C. J. 1989. Ecological Methodology. Harper Collins Publishers. 654 pp.

Schumacher, I. M., M. B. Brown, E. R, Jacobson, B. R. Collins, and P. A. Klein. 1993. Detection of antibodies to a pathogenic *Mycoplasma* in desert tortoises (*Gopherus agassizii*) with upper respiratory tract disease. Journal of Clinical Microbiology 31(6): 1454-1460.

Schumacher, I. M., D. B. Hardenbrook, M. B. Brown, E. R, Jacobson, and P. A. Klein. 1997. Relationship between clinical signs of upper respiratory tract disease and antibodies to *Mycoplasma agassizii* in desert tortoises from Nevada. Journal of Wildlife Diseases 33(2):261-266.

United States Fish and Wildlife Service. 1991. Endangered and threatened wildlife and plants; Finding on a petition to list the Sonoran desert tortoise as threatened or endangered. 56 Fed. Reg. 29453 (June 27, 1991).

United States Fish and Wildlife Service. 1994. Desert tortoise (Mojave population) recovery plan. U.S. Fish and Wildlife Service, Portland, OR:73 pp.

Woodman, P., E. Bernstein, P. Frank, D. Kent, L. Pavliscak, and J. Smith. 2002. Desert tortoise population survey at five plots in Arizona, Fall, 2001. Report to Arizona Game and Fish Dept., Phoenix, AZ.

Woodman, P., E. Bernstein, C. Furman, L. Pavliscak, C. Spake, J. Smith, and K. Wright. 2003. Desert tortoise population survey at five plots in Arizona, Fall, 2002. Report to Arizona Game and Fish Dept., Phoenix, AZ.

Woodman, P., P. Frank, C. Keaton, B. Reiley, and J. Smith. 2004. Desert tortoise population survey at four plots in Arizona, Fall, 2003. Report to Arizona Game and Fish Dept., Phoenix, AZ.

Woodman, P., P. Frank, E. Green, C. Keaton, B. Reiley, and J. Smith. 2005. Desert tortoise population survey at four plots in Arizona, Fall, 2004. Report to Arizona Game and Fish Dept., Phoenix, AZ.

Woodman, P., J. Smith, B. Reiley, and E. Green. 2006. Desert tortoise population survey at three plots in Arizona, Fall, 2005. Report to Arizona Game and Fish Dept., Phoenix, AZ.

Woodman, P., J. Smith, and B. Reiley. 2007. Desert tortoise population survey at four plots in Arizona, Fall, 2006. Report to Arizona Game and Fish Dept., Phoenix, AZ.